Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels

July 2020

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Rules updating

The Rules are generally published annually and changed through a system of Notices between releases.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Offshore Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

Direct calculations

The Rules may require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to LR's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

July 2020

1 PREAMBLE

Section

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The purpose of this Code is to provide an international standard for ships using low-flashpoint fuel, other than ships covered by the *IGC Code*.

The basic philosophy of this Code is to provide mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuels involved.

Throughout the development of this Code it was recognized that it must be based upon sound naval architectural and engineering principles and the best understanding available of current operational experience, field data and research and development. Due to the rapidly evolving new fuels technology, the Organization will periodically review this Code, taking into account both experience and technical developments.

This Code addresses all areas that need special consideration for the usage of the low-flashpoint fuel. The basic philosophy of the IGF Code considers the goal based approach (MSC.1/Circ.1394). Therefore, goals and functional requirements were specified for each section forming the basis for the design, construction and operation.

The current version of this Code includes regulations to meet the functional requirements for natural gas fuel. Regulations for other low-flashpoint fuels will be added to this Code as, and when, they are developed by the Organization.

In the meantime, for other low-flashpoint fuels, compliance with the functional requirements of this Code must be demonstrated through alternative design.

LR 1-01 The IGF Code is divided into a number of 'Parts', where: Parts A and D cover requirements that are generic to all low flashpoint fuels (unless otherwise stated); and Parts A-1, B-1 and C-1 cover specific requirements for ships using natural gas as fuel. Parts A-2, etc. are being developed for low flashpoint fuels other than natural gas. Until these specific requirements are included in the *IGF Code*, then ships using a low flashpoint fuel other than natural gas need to meet alternative design requirements as noted in Part A, 2.3.

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2 General

2.1 Application

Unless expressly provided otherwise this Code applies to ships to which part G of SOLAS chapter II-1 applies.

LR 2.1-01 These Rules specify requirements for the use of gases or other low-flashpoint fuels as a fuel for ships other than ships covered by the *IGC Code* (e.g. LNG carriers).

LR 2.1-02 The requirements are in addition to the applicable requirements of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), *Rules and Regulations for the Classification of Naval Ships*, *Rules and Regulations for the Classification of Inland Waterways Ships*, *Rules for the Classification of Methanol Fuelled Ships*, *Rules and Regulations for the Classification of Special Service Craft* and statutory conventions such as *SOLAS* and *MARPOL*.

LR 2.1-03 Inland Waterways Vessels are to meet the requirements of these Rules. Where it is not possible or it is not appropriate for Inland Waterways Vessels to comply with the specific requirements of these Rules as a result of national or regional requirements, details of the design that deviate from the LR requirements are to be submitted for consideration, *see LR 2.1-05*

LR 2.1-04 The Rules do not repeat the general requirements for fire safety as stated in statutory conventions.

LR 2.1-05 Additional requirements may be imposed by the National Administration with which the ship is registered and/or by the Administration within whose territorial jurisdiction the ship is intended to operate.

LR 2.1-06 The periodic survey regulations for natural gas fuel installations are located in the *Rules and Regulations for the Classification of Ships*, *Part 1, Chapter 3, Section 24*.

LR 2.1-07 Class notation and descriptive note

LR 2.1-07a Ships complying with the requirements of these Rules and fuelled by natural gas (LNG) will be eligible for assignment of the **LFPF(GF, NG)** machinery notation.

LFPF(GF, NG) Assigned to ships other than liquefied gas carriers and tankers, where the main propelling and/or auxiliary machinery is designed to operate on natural gas, or a combination of natural gas and oil fuel. The notation indicates that the natural gas-fuelled machinery has been designed, constructed, arranged, installed and tested in accordance with LR's Rules and Regulations.

LR 2.1-07b Ships complying with aspects of Sections 1 to 4 and Part A-1 of these Rules may be eligible for the Gas-Fuelled Readiness (**GR**) descriptive note. This descriptive note will be added to column 6 of the *Register Book*. This descriptive note is not an LR class notation and is provided solely for information.

GR Assigned to ships other than liquefied gas carriers and tankers, with the extension of one or more of the following associated characters shown in brackets, detailing the aspects of design and construction that are in accordance with LR's Rules and Regulations in force on the date of 'contract for construction'.

If a ship has been assigned the **LFPF(GF, NG)** notation then it will not be eligible for the **GR** descriptive note. It is also to be noted that further appraisal against the Statutory and LR requirements at the time of commissioning followed by testing and commissioning under survey will be required if assignment of the **LFPF(GF, NG)** notation is requested.

A	The design of the natural gas fuel system has been approved in principle.
S	Enhanced structural reinforcement and appropriate materials have been fitted to support the proposed gas storage tank.

T Gas storage tank, tank master isolation valve, fuel venting arrangements and, where applicable, the fuel storage hold space, structural fire protection and ventilation arrangements for under deck tank locations have been built under survey and installed in accordance with an approved design and certified suitable for natural gas fuel operations.

P All piping and equipment associated with the gas-fuelled system, e.g. pipes, pumps, valves, etc. including all bunkering arrangements and associated access arrangements including structural fire protection as applicable, have been installed in accordance with an approved design and certified fit for natural gas fuel operations.

E Engineering systems have been installed in accordance with the approved design and certified suitable for using gas as a fuel. Applicable control and electrical systems are installed in accordance with the requirements of these Rules. Additional letters, assigned in brackets, identify which items meet the requirements for 'gas-fuelled readiness':

M = main engine(s)

A = auxiliary engines

B = boiler

I = incinerator

For example the descriptive note **GR(A,S, E(M,I))** indicates that:

- the full design of the natural gas fuel system has been appraised and approved in principle;
- the vessel structure is reinforced to support the proposed gas storage tank but the natural gas fuel tank and associated arrangements are not yet installed; and
- the main engine and incinerator are approved, certified and installed ready for natural gas fuel operation, in accordance with the *LR Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels* in force on date of contract for construction for the vessel in question.

LR 2.1-07c Plans and information required to achieve **GR** descriptive note with applicable associated characters described in LR 2.1-07b are given in LR 2.1-08a.

LR 2.1-07d Where parts of the natural gas fuel installation are installed on board in order to maintain the **GR** descriptive note with the applicable associated characters described in LR 2.1-07b, these are to be surveyed as required by the applicable requirements of the survey regulations referenced in LR 2.1-06 and plans and information to be submitted.

LR 2.1-08 Plans and information to be submitted

LR 2.1-08a The following are to be submitted to achieve **GR** descriptive note with applicable associated characters:

(a) **GR(A) 'Approval in Principle'**

Submitted plans are to be sufficient to demonstrate compliance.

- Design screening completed in accordance with *ShipRight Procedure Risk Based Designs* (RBD) requirements.
- Risk assessment to demonstrate the elimination or mitigation of risks from new, novel or alternative designs.
    - Machinery space arrangement for all natural gas fuel equipment and pipework.
    - Vessel General Arrangement (GA) illustrating the location of vent mast, Fuel Storage Hold Space (FSHS), Tank Connection Space (TCS), Gas Valve Unit (GVU), Fuel Preparation Room (FPR), machinery spaces, bunker stations and fuel tanks.
    - Ventilation arrangements for spaces with natural gas fuel equipment and pipework (including ventilated ducts and double-walled pipework).
- Hazardous area plan.
- Fire protection arrangements.
- Fuel gas system process flow diagram.
- Other plans related to the specific installation, as required by LR, for example:
    - Bridge visibility plan (only applicable with deck mounted tanks).
    - Preliminary stability impact evaluation (for tank locations proposed high above the waterline).

(b) **GR(S) 'Structural Reinforcement'**

Full details of the structural reinforcement required to support the proposed natural gas fuel tanks are to be submitted. This is to include details of the proposed fuel tank type, size, location and loadings (dynamic and static) to allow verification of the submitted

structural design and calculations for the tank support arrangements. Special consideration will be given for designs using Type B and membrane tanks and additional information may be required.

(c) **GR(T) 'Tank installed'**

Full details of the tank design are to be submitted as required by the *LR Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels*, in addition to the tank design; the scope of appraisal for this associated character includes all valves directly connected to the tank, tank connection space and pressure relief arrangements. For tanks in under deck locations, the ventilation arrangements and FSHS arrangements are also to be reviewed. The following information is to be submitted:

- Details of the proposed fuel tank type, size, location and loadings (dynamic and static) to allow verification of the submitted structural design and calculations for the tank support arrangements. Special consideration will be given for designs using Type B and membrane tanks, and additional information may be required.
- Detailed design of tank, pressure relief arrangement and master isolation valve(s).
- P & ID for all piping integral to the tank (applicable to Type C tanks).
- Ventilation for tank connection space and fuel storage hold space (if applicable).
- Inert gas and inter-barrier space vent piping plans (if applicable).
- Fire protection (if applicable) and cofferdam arrangement (if applicable), if deviating from prescriptive requirements of SOLAS II-2, Risk assessment in accordance with MSC/Circ.1002.
- Hazardous area plan for tank location and associated ventilation arrangements, including details of electrical equipment to be installed in the identified hazardous areas.
- Risk assessment of the tank design to the extent required for RBD.

(d) **GR(P) 'Piping installed'**

Full details of the piping design are to be submitted as required by the *LR Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels*; the scope of appraisal for this associated character includes all piping from the bunker manifold to the gas storage tank and from the tank master isolation valve to the gas-fuelled consumer(s) including all processing equipment. The following items are to be submitted as a minimum:

- Piping design – bunker piping, natural gas fuel delivery piping.
- Natural gas fuel processing system design.
- Double wall arrangement and GVU (double block and bleed unit(s)).
- Pipe stress analysis (where applicable).
- High pressure analysis (where applicable).
- Structural fire protection plan for fuel preparation room (may be the tank connection space).
- Bunker station and GVU/Gas Combustion Unit (GCU) location and associated hazardous area assessment including details of electrical equipment to be installed in the identified hazardous areas.
- Risk assessment of the piping design to the extent required for RBD.

(e) **GR(E) 'Gas-fuelled machinery installed'**

Plans for the exhaust gas ducting arrangements of all gas-fuelled machinery to be reflected in the descriptive note are to be submitted for appraisal. These requirements apply to all machinery that is to be gas-fuelled, these will be reflected in the additional characters appended to the GR descriptive note (M, A, B and I).

Control and electrical plans submissions are defined in the Rules applicable for the vessel.

LR 2.1-08b In addition to the plans and information required by the relevant Chapters of the Rules for Ships, the following are to be submitted for **LFPF(GF, NG)** machinery notation:

(a) Design statement that defines the service profile of the ship, together with a description of the arrangements, essential services as agreed by LR and the intended operating capability and functionality of the main propulsion and auxiliary systems that use gases or other low-flashpoint fuels as fuel.

(b) Risk assessment studies undertaken to a recognised standard in accordance with LR's *ShipRight Procedure for Risk Based Designs (RBD)* and associated annexes. The studies are to be documented so that the risks and how they are eliminated or mitigated are clearly identified.

(c) Arrangement plans for low-flashpoint fuel bunkering stations, low-flashpoint fuel storage tanks, process equipment and machinery, and their location relative to high fire risk areas, accommodation, service and control spaces, water ballast, oil fuel, and other tanks containing flammable substances.

(d) Process Flow Diagrams (PFDs) and Piping and Instrumentation Diagrams (P & IDs) for all equipment containing low-flashpoint fuel. This is to include all pipework and equipment from the bunker connection through to the engine.

(e) Hazardous area plans (indicating the location of hazardous areas and their openings, access and ventilation arrangements) and studies are required by Sections 12.3 to 12.5.

(f) Schedule of electrical and mechanical equipment located in hazardous areas.

(g) Fuel system plans. Details are to include the maximum potential generation of gas or vapour and the associated systems to handle it under all envisaged operating conditions.

(h) Plans and details of low-flashpoint fuel storage tanks and pressure vessels, including filling and relief arrangements. For LNG fuel storage tanks, *see* Chapter LR IV, Information and Plans, of the Rules for Ships for Liquefied Gases. Also refer to LR 6.4-01, LR 6.4-05, LR 6.4-27, LR 6.4-29 and LR 6.4-30.

(i) Low-flashpoint fuel process equipment plans (e.g. compressors, heat exchangers, etc.).

(j) Low-flashpoint fuel piping system plans with details of piping design including installation and insulation, ducting, valves and fittings, pressure relief, expansion, and ventilation and purging arrangements.

(k) Evidence of fatigue analysis for all pressurised low-flashpoint fuel piping arrangements as required by LR 7.3-04.

(l) Evidence of piping stress analysis as required by 7.3.4.5 and LR 7.3-03.

(m) Ventilation system plans for the machinery spaces, machinery enclosures or casings including air-locks, ventilation hoods, pipe ducting and any dampers in them, closing appliances and the position of the controls for stopping the system. Plans are to indicate hazardous areas where appropriate.

(n) Enclosures or casing plans for low-flashpoint fuelled machinery/equipment and any airlocks where access is required.

(o) Fixed low-flashpoint fuel gas/vapour detection and alarm system plans.

(p) Description of emergency shutdown arrangements, including a list of control, monitoring and alarm points.

(q) Operating manuals that describe the installation particulars, together with operating and maintenance instructions to cover operating modes, start-up, shutdown and fault conditions. Procedures to update safety, alarm or control systems are to be included and are to comply with the requirements of Part 6, Chapter 1 of Rules for Ships. Equipment manufacturers' instructions are to include the drawings and diagrams necessary for start-up commissioning, maintenance, inspection, checking of correct operation, repair of the machinery, the use of correct spares and tools, and useful instructions with regard to safety.

(r) Description and plans of low-flashpoint fuel control and monitoring systems and fuel changeover arrangements for dual-fuelled machinery, including line diagrams of control circuits and lists of monitoring, control and alarm points.

(s) Quality plans for sourcing, design, installation and testing of all components used in the low-flashpoint fuel system installed with the low-flashpoint fuel machinery.

(t) A concept of operation (ConOps) document, where applicable. This may include a statement of an Owner's intentions for the operation of the ship, description on ship's intended service in terms of purpose and function and is to include, but not be limited to, information on the following: crewing, operational speeds, wave heights, displacements, service area, temperatures and motions; arrangements under reasonably foreseeable, normal and abnormal conditions. The ConOps is to be provided by the Owner. LR may accept alternative documents where these provide the information which would be included within the ConOps, in such cases the relevant sections providing the information required to provide equivalence with the ConOps are to be identified.

(u) Evidence of type testing of the engine/turbine with electronic controls. Alternatively, a test plan shall be submitted to verify on board the safe functionality of the electronic control system during all reasonably foreseeable operational conditions as defined in the CONOPs document. The test plan shall identify the foreseeable failure modes.

(v) Schedule of testing at engine/turbine builders and commissioning prior to sea trials, to demonstrate that the low-flashpoint fuelled machinery is capable of operating as described in the design statement. The test schedules are to identify all modes of operation and the sea trials are to include typical port manoeuvres under all intended engine/turbine operating modes.

(w) A cause and effect diagram to indicate the results of activation of each shutdown, shut-off and cut-out associated with the low-flashpoint fuel system including engine operation and bunkering.

(x) A suitable testing and inspection plan for low-flashpoint fuel storage and supply systems trials.

(y) Low-flashpoint fuel bunkering arrangement plans, and operation and maintenance instruction manuals.

(z) Safety philosophy description for the prevention of crankcase explosions. *See* 10.3.

(aa) Structural fire protection plan showing the main fire zones, the fire compartmentation bulkheads and decks within the main fire zones, including fire risk categorisation of spaces and class of all fire divisions; the plan is to also allow identification of different types of space and their use.

(bb) A plan showing the details of construction of the fire protection bulkheads and decks.

(cc) A plan showing the arrangement of fire main system protecting any space included in the fuel storage hold space, fuel containment system, low-flash point fuel storage tanks, and ventilation trunks to such spaces, if any. The plan is to show the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials, and the cross-connections to any other system.

(dd) A plan showing the arrangement of fire-fighting systems (e.g. waterspray) protecting any space included in the fuel storage hold space, fuel containment system, low-flash point fuel storage tanks, and ventilation trunks to such spaces, if any. The plan is to provide details that include calculations for the quantities of the media used and the proposed rates of application.

(ee) A plan of the dry powder system protecting the bunkering station. The plan is to show details of system arrangements, including calculations for the quantities of the media used and the proposed rates of application.

(ff) A fire control plan meeting the requirements of SOLAS Ch. II-2 *Reg. 15.2.4*.

2.2 Definitions

Unless otherwise stated below, definitions are as defined in SOLAS *chapter II-2*.

LR 2.2-01 Except where expressly provided otherwise, the definitions of terms in this Section are to be adopted for classification purposes.

2.2.1 *Accident* means an uncontrolled event that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.

LR 2.2-02 Administration means the Government of the State whose flag the ship is entitled to fly. For the purpose of classification, it is to be taken as Lloyd’s Register.

LR 2.2-03 *Area* means a defined location. An area can be on open deck. An area can be open, semi-enclosed or enclosed. An area can be a space below deck. An area can be hazardous or non-hazardous.

2.2.2 *Breadth (B)* means the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).

LR 2.2-04 For the determination of the scantlings for hull construction, the breadth (*B*) to be taken as defined in Pt 3, Ch 1,6 of the Rules for Ships.

2.2.3 *Bunkering* means the transfer of liquid or gaseous fuel from land based or floating facilities into a ships' permanent tanks or connection of portable tanks to the fuel supply system.

2.2.4 *Certified safe type* means electrical equipment that is certified safe by the relevant authorities recognized by the Administration for operation in a flammable atmosphere based on a recognized standard.[1]

2.2.5 *CNG* means compressed natural gas (see also 2.2.26).

2.2.6 *Control station* means those spaces defined in SOLAS *chapter II-2* and additionally for this Code, the engine control room.

LR 2.2-05 *Dependability* is as defined in IEC 60050(191): Quality vocabulary — Part 3: Availability, reliability and maintainability terms — Section 3.2: Glossary of international terms. It is the collective term used to describe the availability performance and its influencing factors: reliability performance, maintainability performance and maintenance support performance and relates to essential services as agreed with Lloyd’s Register.

Note: Dependability is used only for general descriptions in non-quantitative terms.

2.2.7 *Design temperature* for selection of materials is the minimum temperature at which liquefied gas fuel may be loaded or transported in the liquefied gas fuel tanks.

2.2.8 *Design vapour pressure* "P_0" is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank.

[1] Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

2.2.9 *Double block and bleed valve* means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way valve and a closing valve instead of three separate valves.

2.2.10 *Dual fuel* engines means engines that employ fuel covered by this Code (with pilot fuel) and oil fuel. Oil fuels may include distillate and residual fuels.

2.2.11 *Enclosed space* means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally.[2]

LR 2.2-06 *Enclosed space* is any space where, in the absence of artificial ventilation, an explosive atmosphere will not be dispersed naturally. In practical terms, an enclosed space is bounded either on all sides, or all but one side, by bulkheads and decks irrespective of openings, such that the required ventilation rate to prevent the accumulation of pockets of stagnant air cannot be achieved by natural ventilation alone.

2.2.12 *ESD* means emergency shutdown.

LR 2.2-07 *Essential services* mean propulsion, electrical power and other facilities and/or amenities necessary for the safety of the ship and its occupants.

2.2.13 *Explosion* means a deflagration event of uncontrolled combustion.

2.2.14 *Explosion pressure relief* means measures provided to prevent the explosion pressure in a container or an enclosed space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings.

LR 2.2-08 *Explosive gas atmosphere* is a mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour that, after ignition, permits self-sustaining flame propagation.

2.2.15 *Fuel containment system* is the arrangement for the storage of fuel including tank connections. It includes where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the fuel storage hold space.

The spaces around the fuel tank are defined as follows:

.1 *Fuel storage hold space* is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space;

.2 *Interbarrier space* is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and

.3 *Tank connection space* is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

LR 2.2-09 In order to minimise the extent of hazardous areas on open deck or to provide environmental protection to essential safety equipment (e.g. tank valves, safety valves etc.) related to tanks or both, the installation of a tank connection space on open deck is permitted.

LR 2.2-10 A tank connection space is permitted to contain equipment such as vaporizers or heat exchangers. Such equipment is considered to contain only potential sources of release, but not sources of ignition.

2.2.16 *Filling limit (FL)* means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature.

2.2.17 *Fuel preparation room* means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes.

LR 2.2-11 Where the space containing equipment such as vaporisers or heat exchangers contains only potential sources of release, but not sources of ignition, then it may be considered a tank connection space and not a fuel preparation room.

2.2.18 *Gas* means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C.

2.2.19 *Gas consumer* means any unit within the ship using gas as a fuel.

2.2.20 *Gas only engine* means an engine capable of operating only on gas, and not able to switch over to operation on any other type of fuel.

2.2.21 *Hazardous area* means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment.

[2] See also definition in IEC 60092-502:1999.

LR 2.2-12 *Hazardous areas*, as defined in the IEC 60079 series are classified into zones based upon the frequency of the occurrence and duration of an explosive gas atmosphere.

2.2.22 *High pressure* means a maximum working pressure greater than 1.0 MPa.

2.2.23 *Independent tanks* are self-supporting, do not form part of the ship's hull and are not essential to the hull strength.

LR 2.2-13 A Type C tank is an independent tank designed in accordance with pressure vessel requirements for liquefied gas tanks in Chapters 2, 3, 4 and 6 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* (hereinafter referred to as the Rules for Ships for Liquefied Gases), and Class 1 fusion welded pressure vessels in *Pt 5, Ch 1* of the Rules for Ships.

2.2.24 *LEL* means the lower explosive limit.

2.2.25 *Length (L)* is the length as defined in the International Convention on Load Lines in force.

2.2.26 *LNG* means liquefied natural gas.

2.2.27 *Loading limit (LL)* means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

2.2.28 *Low-flashpoint fuel* means gaseous or liquid fuel having a flashpoint lower than otherwise permitted under paragraph 2.1.1 of *SOLAS regulation II-2/4*.

2.2.29 *MARVS* means the maximum allowable relief valve setting.

LR 2.2-14 *Master gas fuel valve* is a remotely activated and system activated valve in the gas supply line to the low-flashpoint fuelled machinery which is located outside the machinery space and is as close as possible to the low-flashpoint fuel preparation equipment.

2.2.30 *MAWP* means the maximum allowable working pressure of a system component or tank.

2.2.31 *Membrane tanks* are non-self-supporting tanks that consist of a thin liquid and gas tight layer (membrane) supported through insulation by the adjacent hull structure.

2.2.32 *Multi-fuel engines* means engines that can use two or more different fuels that are separate from each other.

2.2.33 *Non-hazardous area* means an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment.

2.2.34 *Open deck* means a deck having no significant fire risk that at least is open on both ends/sides, or is open on one end and is provided with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side plating or deckhead.

LR 2.2-15 A *reasonably foreseeable abnormal condition* is an event, incident or failure that:

(a) has happened and could happen again;

(b) is planned for (e.g. emergency actions cover such a situation, maintenance is undertaken to prevent it, etc.).

2.2.35 *Risk* is an expression for the combination of the likelihood and the severity of the consequences.

LR 2.2-16 *Risk assessment* is the evaluation of likelihood and consequence together with a judgement on the significance of the result, *see* IEC/ISO 31010: Risk management, risk assessment techniques.

2.2.36 *Reference temperature* means the temperature corresponding to the vapour pressure of the fuel in a fuel tank at the set pressure of the pressure relief valves (PRVs).

LR 2.2-17 *Rollover* is where stored liquid develops layers of liquid with different densities and temperatures, and once the surface between these layers can no longer be maintained, significant gas/vapour generation occurs. This generation of gas can result in a significant increase in pressure within the storage tank.

LR 2.2-18 *Rules for Ships* means the *Rules and Regulations for the Classification of Ships*.

LR 2.2-19 *Rules for Ships for Liquefied Gases* means the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk*.

LR 2.2-20 *Rules for Materials* means the *Rules for the Manufacture, Testing and Certification of Materials*.

2.2.37 *Secondary barrier* is the liquid-resisting outer element of a fuel containment system designed to afford temporary containment of any envisaged leakage of liquid fuel through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level.

2.2.38 *Semi-enclosed space* means a space where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur.[3]

LR 2.2-21 *Single failure* is where loss of intended function occurs through one fault or action.

2.2.39 *Source of release* means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere could be formed.

LR 2.2-22 *Space* means an enclosed or semi-enclosed area, room or location.

LR 2.2-23 *Tank master isolation valve(TMIV)*is a remotely operated valve on a liquefied gas pipe from a liquefied gas storage tank. The valve is located as close as possible to the tank outlet.

2.2.40 *Unacceptable loss of power* means that it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation *II-1/26.3*.

2.2.41 *Vapour pressure* is the equilibrium pressure of the saturated vapour above the liquid, expressed in MPa absolute at a specified temperature.

2.3 Alternative design

2.3.1 This Code contains functional requirements for all appliances and arrangements related to the usage of low-flashpoint fuels.

2.3.2 Fuels, appliances and arrangements of low-flashpoint fuel systems may either:

.1 deviate from those set out in this Code, or

.2 be designed for use of a fuel not specifically addressed in this Code.

Such fuels, appliances and arrangements can be used provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

2.3.3 The equivalence of the alternative design shall be demonstrated as specified in *SOLAS regulation II-1/55* and approved by the Administration. However, the Administration shall not allow operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by this Code.

LR 2.3-01 LR can consider alternative design proposals for approval by the Administration.

■

3 GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

The goal of this Code is to provide for safe and environmentally-friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using gas or low-flashpoint fuel as fuel.

3.2 Functional requirements

3.2.1 The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.

3.2.2 The probability and consequences of fuel-related hazards shall be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions shall be initiated.

3.2.3 The design philosophy shall ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.

LR 3.2-01 The requirement given in 3.2.3 is applicable to gas fuels and to all low flashpoint fuels.

[3] Refer also to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

3.2.4 Hazardous areas shall be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.

3.2.5 Equipment installed in hazardous areas shall be minimized to that required for operational purposes and shall be suitably and appropriately certified.

3.2.6 Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented.

3.2.7 System components shall be protected against external damages.

3.2.8 Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions.

3.2.9 It shall be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system shall be designed to prevent venting under all normal operating conditions including idle periods.

3.2.10 Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.

3.2.11 Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space shall be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

3.2.13 Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.

3.2.14 Fixed gas detection suitable for all spaces and areas concerned shall be arranged.

3.2.15 Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.

3.2.16 Commissioning, trials and maintenance of fuel systems and gas utilization machinery shall satisfy the goal in terms of safety, availability and reliability.

3.2.17 The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

3.2.18 A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.

4 General Requirements

4.1 Goal

The goal of this chapter is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.

LR 4.1-01 Where the risks cannot be eliminated, an inherently safer design is to be sought in preference to operational or procedural controls and this is to be consistent with 2.3.3. This is to focus on engineered prevention of failure, that is, a minimised number of connections, increased reliability and redundancy. Where this cannot be achieved or is insufficient, protection of occupants is to focus on:

(a) firstly, passive means, such as physical barriers, separation and absence of ignition sources; and

(b) secondly, active means, such as detection, isolation, ventilation and extinguishment.

Both passive and active means may be required to demonstrate an appropriate level of safety.

4.2 Risk assessment

4.2.1 A risk assessment shall be conducted to ensure that risks arising from the use of low-flashpoint fuels affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration shall be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

LR 4.2-01 The risk assessment is to be undertaken and documented in accordance with LR's *ShipRight Procedure for Risk Based Designs (RBD) and associated annexes*. Consideration of hazards is to include fuel and inert gas tanks, machinery and equipment, and the specific location of accommodation and cargo.

4.2.2 For ships to which part A-1 applies, the risk assessment required by 4.2.1 need only be conducted where explicitly required by paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10 as well as by paragraphs 4.4 and 6.8 of the annex.

LR 4.2-02 To comply with 4.2.2 the risk assessment for ships to which part A-1 applies is to be undertaken and documented in accordance with LR's *ShipRight Procedure for Risk Based Designs (RBD) and associated annexes*.

4.2.3 The risks shall be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock shall as a minimum be considered. The analysis shall ensure that risks are eliminated wherever possible. Risks which cannot be eliminated shall be mitigated as necessary. Details of risks, and the means by which they are mitigated, shall be documented to the satisfaction of the Administration.

4.3 Limitation of explosion consequences

An explosion in any space containing any potential sources of release[4] and potential ignition sources shall not:

.1 cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;

.2 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;

.3 damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;

.4 disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;

.5 damage life-saving equipment or associated launching arrangements;

.6 disrupt the proper functioning of firefighting equipment located outside the explosion-damaged space;

.7 affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or

.8 prevent persons access to life-saving appliances or impede escape routes.

[4] Double wall fuel pipes are not considered as potential sources of release.

Contents

Section
Part A-1 - Specific Requirements for Ships Using Natural Gas as Fuel

■

Part A-1 - Specific Requirements for Ships Using Natural Gas as Fuel

Fuel in the context of the regulations in this part means natural gas, either in its liquefied or gaseous state.

It should be recognized that the composition of natural gas may vary depending on the source of natural gas and the processing of the gas.

5 Ship Design and Arrangement

5.1 Goal

The goal of this chapter is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refuelling systems.

5.2 Functional requirements

5.2.1 This chapter is related to functional requirements in 3.2.1 to 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12 to 3.2.15 and 3.2.17. In particular the following apply:

.1 the fuel tank(s) shall be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship;

.2 fuel containment systems, fuel piping and other fuel sources of release shall be so located and arranged that released gas is led to a safe location in the open air;

.3 the access or other openings to spaces containing fuel sources of release shall be so arranged that flammable, asphyxiating or toxic gas cannot escape to spaces that are not designed for the presence of such gases

.4 fuel piping shall be protected against mechanical damage;

.5 the propulsion and fuel supply system shall be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

.6 the probability of a gas explosion in a machinery space with gas or low-flashpoint fuelled machinery shall be minimized.

5.3 Regulations – General

5.3.1 Fuel storage tanks shall be protected against mechanical damage.

5.3.2 Fuel storage tanks and or equipment located on open deck shall be located to ensure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

5.3.3 The fuel tank(s) shall be protected from external damage caused by collision or grounding in the following way:

.1 The fuel tanks shall be located at a minimum distance of B/5 or 11.5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught;

where:

B is the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to *SOLAS regulation II-1/2.8*).

.2 The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

.3 For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.

.4 In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

.1 For passenger ships: B/10 but in no case less than 0.8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11.5 m, whichever is less, as required by 5.3.3.1.

.2 For cargo ships:

.1 for V_c below or equal 1,000 m^3, 0.8 m;

.2 for 1,000 $m^3 < V_c <$ 5,000 m^3, 0.75 + V_c x 0.2/4,000 m;

.3 for 5,000 $m^3 \leq Vc <$ 30,000 m^3, 0.8 + V_c/25,000 m; and

.4 for $V_c \geq$ 30,000 m^3, 2 m,

where:

V_c corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

.5 The lowermost boundary of the fuel tank(s) shall be located above the minimum distance of B/15 or 2.0 m, whichever is less, measured from the moulded line of the bottom shell plating at the centreline.

.6 For multihull ships the value of B may be specially considered.

.7 The fuel tank(s) shall be abaft a transverse plane at 0.08L measured from the forward perpendicular in accordance with *SOLAS regulation II-1/8.1* for passenger ships, and abaft the collision bulkhead for cargo ships.

where:

L is the length as defined in the International Convention on Load Lines (refer to *SOLAS regulation II-1/2.5*).

.8 For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3.

LR 5.3-01 The Tank Master Isolation Valve (TMIV) and pipework from the TMIV to the fuel tank shall be located at the minimum distance required for the fuel tank as determined by 5.3.3.

LR 5.3-02 Subject to agreement by the National Administration, physical protection of fuel tanks from collisions and groundings may be provided where the protection is equivalent to the intent of 5.3.3 and the boundary of the fuel tank is not closer to the shell plating or aft terminal than determined by 5.3.4.

5.3.4 As an alternative to 5.3.3.1 above, the following calculation method may be used to determine the acceptable location of the fuel tanks:

.1 The value f_{CN} calculated as described in the following shall be less than 0.02 for passenger ships and 0.04 for cargo ships.[5]

.2 The f_{CN} is calculated by the following formulation:

$f_{CN} = f_l \text{ X } f_t \text{ X } f_v$

where:

f_l is calculated by use of the formulations for factor p contained in *SOLAS regulation II-1/7-1.1.1.1*. The value of x1 shall correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of x 2 shall correspond to the distance from the aft terminal to the foremost boundary of the fuel tank.

f_t is calculated by use of the formulations for factor r contained in *SOLAS regulation II-1/7-1.1.2*, and reflects the probability that the damage penetrates beyond the outer boundary of the fuel tank. The formulation is:

$f_t = 1 - r(x1, x2, b)$ [6]

[5] The value f_{CN} accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.

[6] When the outermost boundary of the fuel tank is outside the boundary given by the deepest subdivision waterline the value of b should be taken as 0.

f_v is calculated by use of the formulations for factor v contained in *SOLAS regulation II-1/7-2.6.1.1* and reflects the probability that the damage is not extending vertically above the lowermost boundary of the fuel tank. The formulations to be used are:

f_v = 1.0 - 0.8 · ((*H* - *d*) /7.8), if (*H* - *d*) is less than or equal to 7.8 m. f_v shall not be taken greater than 1.

f_v = 0.2 - (0.2 · ((*H* - *d*) - 7.8)/4.7), in all other cases f_v shall not be taken less than 0.

where:

H is the distance from baseline, in metres, to the lowermost boundary of the fuel tank; and

d is the deepest draught (summer load line draught).

.3 The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

.4 For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.

.5 In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

.1 For passenger ships: B/10 but in no case less than 0.8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11.5 m, whichever is less, as required by 5.3.3.1.

.2 For cargo ships:

.1 for V_c below or equal 1,000 m^3, 0.8 m;

.2 for 1,000 m^3 < V_c < 5,000 m^3, 0.75+ V_c x 0.2/4,000 m;

.3 for 5,000 m^3 ≤ V_c < 30,000 m^3, 0.8 + V_c/25,000 m; and

.4 for V_c ≥ 30,000 m^3, 2 m,

where:

V_c corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

.6 In case of more than one non-overlapping fuel tank located in the longitudinal direction, f_{CN} shall be calculated in accordance with paragraph 5.3.4.2 for each fuel tank separately. The value used for the complete fuel tank arrangement is the sum of all values for f_{CN} obtained for each separate tank.

.7 In case the fuel tank arrangement is unsymmetrical about the centreline of the ship, the calculations of f_{CN} shall be calculated on both starboard and port side and the average value shall be used for the assessment. The minimum distance as set forth in paragraph 5.3.4.5 shall be met on both sides.

.8 For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with section 2.3.

5.3.5 When fuel is carried in a fuel containment system requiring a complete or partial secondary barrier:

.1 fuel storage hold spaces shall be segregated from the sea by a double bottom; and

.2 the ship shall also have a longitudinal bulkhead forming side tanks.

5.4 Machinery space concepts

5.4.1 In order to minimize the probability of a gas explosion in a machinery space with gas-fuelled machinery one of these two alternative concepts may be applied:

.1 Gas safe machinery spaces: Arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

In a gas safe machinery space a single failure cannot lead to release of fuel gas into the machinery space.

.2 ESD-protected machinery spaces: Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery shall be automatically executed while equipment or machinery in use or active during these conditions shall be of a certified safe type.

In an ESD protected machinery space a single failure may result in a gas release into the space. Venting is designed to accommodate a probable maximum leakage scenario due to technical failures.

Failures leading to dangerous gas concentrations, e.g. gas pipe ruptures or blow out of gaskets are covered by explosion pressure relief devices and ESD arrangements.

LR 5.4-01 With respect to 5.4.1.2, electrical equipment not of a certified safe type shall be automatically disconnected in the event of abnormal conditions involving gas hazards, *see* 2.2.4.

LR 5.4-02 Premixed engines using fuel gas mixed with air before the turbocharger shall be ESD protected.

LR 5.4-03 Regulations for gas turbines are located in 10.5.

5.5 Regulations for gas safe machinery space

5.5.1 A single failure within the fuel system shall not lead to a gas release into the machinery space.

5.5.2 All fuel piping within machinery space boundaries shall be enclosed in a gas tight enclosure in accordance with 9.6.

5.6 Regulations for ESD-protected machinery spaces

5.6.1 ESD protection shall be limited to machinery spaces that are certified for periodically unattended operation.

5.6.2 Measures shall be applied to protect against explosion, damage of areas outside of the machinery space and ensure redundancy of power supply. The following arrangement shall be provided but may not be limited to:

.1 gas detector;

.2 shutoff valve;

.3 redundancy; and

.4 efficient ventilation.

LR 5.6-01 A description of the ESD philosophy is to be submitted demonstrating how the probability of a gas explosion will be minimised and is to include the following as a minimum:

(a) a hazardous area classification study in accordance with 60079-10-1, *see* 12.3;

(b) the risk assessment described in 4.2;

(c) the systems and equipment which will be isolated;

(d) the systems and equipment which will remain operational;

(e) ventilation rates during ESD procedure;

(f) performance of gas detection systems when high ventilation rates are present and;

(g) equipment classification for the certified safe type which is to remain operational.

5.6.3 Gas supply piping within machinery spaces may be accepted without a gastight external enclosure on the following conditions:

.1 Engines for generating propulsion power and electric power shall be located in two or more machinery spaces not having any common boundaries unless it can be documented that a single casualty will not affect both spaces.

.2 The gas machinery space shall contain only a minimum of such necessary equipment, components and systems as are required to ensure that the gas machinery maintains its function.

.3 A fixed gas detection system arranged to automatically shutdown the gas supply, and disconnect all electrical equipment or installations not of a certified safe type, shall be fitted.

5.6.4 Distribution of engines between the different machinery spaces shall be such that shutdown of fuel supply to any one machinery space does not lead to an unacceptable loss of power.

LR 5.6-02 Where gas leakage in an ESD-protected machinery space would result in the shutdown of the engine(s) in that space, sufficient propulsion and manoeuvring capability including essential and safety systems is to be maintained. The minimum power to be maintained shall be assessed from the operational characteristics of the ship, subject to consideration by LR. The safety concept of the engine shall clearly indicate application of the 'double wall' or 'single wall' arrangement. It shall be noted that the 'safety concept' is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures. A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

5.6.5 ESD protected machinery spaces separated by a single bulkhead shall have sufficient strength to withstand the effects of a local gas explosion in either space, without affecting the integrity of the adjacent space and equipment within that space.

5.6.6 ESD protected machinery spaces shall be designed to provide a geometrical shape that will minimize the accumulation of gases or formation of gas pockets.

5.6.7 The ventilation system of ESD-protected machinery spaces shall be arranged in accordance with 13.5.

5.7 Regulations for location and protection of fuel piping

5.7.1 Fuel pipes shall not be located less than 800 mm from the ship's side.

5.7.2 Fuel piping shall not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the *SOLAS Convention*.

5.7.3 Fuel pipes led through ro-ro spaces, special category spaces and on open decks shall be protected against mechanical damage.

5.7.4 Gas fuel piping in ESD protected machinery spaces shall be located as far as practicable from the electrical installations and tanks containing flammable liquids.

5.7.5 Gas fuel piping in ESD protected machinery spaces shall be protected against mechanical damage.

5.8 Regulations for fuel preparation room design

Fuel preparation rooms shall be located on an open deck, unless those rooms are arranged and fitted in accordance with the regulations of this Code for tank connection spaces.

LR 5.8-01 Fuel preparation rooms, regardless of location, shall be arranged to safely contain any cryogenic leakages.

LR 5.8-02 The material of the boundaries of the fuel preparation room shall have a design temperature corresponding to the lowest temperature it can be subjected to in a probable maximum leakage scenario unless the boundaries of the space, i.e. bulkheads and decks, are provided with suitable thermal protection.

LR 5.8-03 The fuel preparation room shall be arranged to prevent surrounding hull structure from being exposed to unacceptable cooling, in case of leakage of cryogenic liquids.

LR 5.8-04 The fuel preparation room shall be designed to withstand the maximum pressure build up during such a leakage. The pressure relief venting via the vent mast shall be in accordance with the applicable requirements indicated in 6.7.2.

5.9 Regulations for bilge systems

5.9.1 Bilge systems installed in areas where fuel covered by this Code can be present shall be segregated from the bilge system of spaces where fuel cannot be present.

5.9.2 Where fuel is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided. The bilge system shall not lead to pumps in safe spaces. Means of detecting such leakage shall be provided.

5.9.3 The hold or interbarrier spaces of type A independent tanks for liquid gas shall be provided with a drainage system suitable for handling liquid fuel in the event of fuel tank leakage or rupture.

5.10 Regulations for drip trays

5.10.1 Drip trays shall be fitted where leakage may occur which can cause damage to the ship structure or where limitation of the area which is effected from a spill is necessary.

5.10.2 Drip trays shall be made of suitable material.

LR 5.10-01 Suitable material is to ensure any leakage cannot come into contact with other equipment/structures and is safely collected. In this regard the integrity of the drip tray is to be maintained if subjected to cryogenic temperatures associated with LNG leakages.

5.10.3 The drip tray shall be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid fuel.

5.10.4 Each tray shall be fitted with a drain valve to enable rain water to be drained over the ship's side.

5.10.5 Each tray shall have a sufficient capacity to ensure that the maximum amount of spill according to the risk assessment can be handled.

5.11 Regulations for arrangement of entrances and other openings in enclosed spaces

5.11.1 Direct access shall not be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock which complies with 5.12 shall be provided.

5.11.2 If the fuel preparation room is approved located below deck, the room shall, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an airlock which complies with 5.12 shall be provided.

5.11.3 Unless access to the tank connection space is independent and direct from open deck it shall be arranged as a bolted hatch. The space containing the bolted hatch will be a hazardous space.

LR 5.11-01 Subject to agreement by the National Administration, consideration will be given to direct access from a non-hazardous area to a zone 2 hazardous area where the zone 2 area has a bolted hatch that provides direct access into, for example a tank connection space. Refer to *LR 12.5-03*.

5.11.4 If the access to an ESD-protected machinery space is from another enclosed space in the ship, the entrances shall be arranged with an airlock which complies with 5.12.

5.11.5 For inerted spaces access arrangements shall be such that unintended entry by personnel shall be prevented. If access to such spaces is not from an open deck, sealing arrangements shall ensure that leakages of inert gas to adjacent spaces are prevented.

5.12 Regulations for airlocks

5.12.1 An airlock is a space enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1.5 m and not more than 2.5 m apart. Unless subject to the requirements of the International Convention on Load Lines, the door sill shall not be less than 300 mm in height. The doors shall be self-closing without any holding back arrangements.

5.12.2 Airlocks shall be mechanically ventilated at an overpressure relative to the adjacent hazardous area or space.

5.12.3 The airlock shall be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events shall be evaluated in the risk analysis according to 4.2.

5.12.4 Airlocks shall have a simple geometrical form. They shall provide free and easy passage, and shall have a deck area not less than 1.5 m^2. Airlocks shall not be used for other purposes, for instance as store rooms.

5.12.5 An audible and visual alarm system to give a warning on both sides of the airlock shall be provided to indicate if more than one door is moved from the closed position.

5.12.6 For non-hazardous spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of underpressure in the hazardous space access to the space is to be restricted until the ventilation has been reinstated. Audible and visual alarms shall be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost.

5.12.7 Essential equipment required for safety shall not be de-energized and shall be of a certified safe type. This may include lighting, fire detection, public address, general alarms systems.

6 Fuel Containment System

6.1 Goal

The goal of this chapter is to provide that gas storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil fuelled ship.

6.2 Functional requirements

This chapter relates to functional requirements in 3.2.1, 3.2.2, 3.2.5 and 3.2.8 to 3.2.17. In particular the following apply:

.1 the fuel containment system shall be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:

.1 exposure of ship materials to temperatures below acceptable limits;

.2 flammable fuels spreading to locations with ignition sources;

.3 toxicity potential and risk of oxygen deficiency due to fuels and inert gases;

.4 restriction of access to muster stations, escape routes and life-saving appliances (LSA); and

.5 reduction in availability of LSA.

.2 the pressure and temperature in the fuel tank shall be kept within the design limits of the containment system and possible carriage requirements of the fuel;

.3 the fuel containment arrangement shall be so designed that safety actions after any gas leakage do not lead to an unacceptable loss of power; and

.4 if portable tanks are used for fuel storage, the design of the fuel containment system shall be equivalent to permanent installed tanks as described in this chapter.

6.3 Regulations – General

6.3.1 Natural gas in a liquid state may be stored with a maximum allowable relief valve setting (MARVS) of up to 1.0 MPa.

6.3.2 The Maximum Allowable Working Pressure (MAWP) of the gas fuel tank shall not exceed 90% of the Maximum Allowable Relief Valve Setting (MARVS).

6.3.3 A fuel containment system located below deck shall be gas tight towards adjacent spaces.

6.3.4 All tank connections, fittings, flanges and tank valves must be enclosed in gas tight tank connection spaces, unless the tank connections are on open deck. The space shall be able to safely contain leakage from the tank in case of leakage from the tank connections.

LR 6.3-01 To safely contain leakage, the tank connection space is to be designed to withstand the maximum calculated pressure within the space, the lowest temperature it could be subjected to, and the weight of accumulated liquid. This is to consider the rate and volume of release, relief venting to a safe location, and thermal isolation of tank connection space supports from the fuel storage tank and deck. The calculations to determine the possible leakage rate are to be submitted.

6.3.5 Pipe connections to the fuel storage tank shall be mounted above the highest liquid level in the tanks, except for fuel storage tanks of type C. Connections below the highest liquid level may however also be accepted for other tank types after special consideration by the Administration.

6.3.6 Piping between the tank and the first valve which release liquid in case of pipe failure shall have equivalent safety as the type C tank, with dynamic stress not exceeding the values given in 6.4.15.3.1.2.

6.3.7 The material of the bulkheads of the tank connection space shall have a design temperature corresponding with the lowest temperature it can be subject to in a probable maximum leakage scenario. The tank connection space shall be designed to withstand the maximum pressure build up during such a leakage. Alternatively, pressure relief venting to a safe location (mast) can be provided.

6.3.8 The probable maximum leakage into the tank connection space shall be determined based on detail design, detection and shutdown systems.

LR 6.3-02 The probable maximum leakage is to be agreed with LR.

6.3.9 If piping is connected below the liquid level of the tank it has to be protected by a secondary barrier up to the first valve.

6.3.10 If liquefied gas fuel storage tanks are located on open deck the ship steel shall be protected from potential leakages from tank connections and other sources of leakage by use of drip trays. The material is to have a design temperature corresponding to the temperature of the fuel carried at atmospheric pressure. The normal operation pressure of the tanks shall be taken into consideration for protecting the steel structure of the ship.

LR 6.3-03 Where the storage tank is located below the open deck, but the tank connections are on the open deck, drip trays are to be provided to protect the deck from leakages from tank connections and other sources of leakage.

LR 6.3-04 Where the storage tank and the tank connections are located below the deck, all tank connections are to be located in a tank connection space. Drip trays are not required in this case.

6.3.11 Means shall be provided whereby liquefied gas in the storage tanks can be safely emptied.

6.3.12 It shall be possible to empty, purge and vent fuel storage tanks with fuel piping systems. Instructions for carrying out these procedures must be available on board. Inerting shall be performed with an inert gas prior to venting with dry air to avoid an explosion hazardous atmosphere in tanks and fuel pipes. See detailed regulations in 6.10.

6.4 Regulations for liquefied gas fuel containment

6.4.1 General

6.4.1.1 The risk assessment required in 4.2 shall include evaluation of the ship's liquefied gas fuel containment system, and may lead to additional safety measures for integration into the overall vessel design.

LR 6.4-01 Details of the proposed design of containment systems are to be submitted for consideration, and it is recommended this is done at the earliest stage possible. For a description of LR's system of approval, refer to the *ShipRight Procedure Additional Design Procedures - Approval Scheme for Gas Ship Containment Systems*.

6.4.1.2 The design life of fixed liquefied gas fuel containment system shall not be less than the design life of the ship or 20 years, whichever is greater.

6.4.1.3 The design life of portable tanks shall not be less than 20 years.

6.4.1.4 Liquefied gas fuel containment systems shall be designed in accordance with North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. Less demanding environmental conditions, consistent with the expected usage, may be accepted by the Administration for liquefied gas fuel containment systems used exclusively for restricted navigation. More demanding environmental conditions may be required for liquefied gas fuel containment systems operated in conditions more severe than the North Atlantic environment. [7,8]

6.4.1.5 Liquefied gas fuel containment systems shall be designed with suitable safety margins:

.1 to withstand, in the intact condition, the environmental conditions anticipated for the liquefied gas fuel containment system's design life and the loading conditions appropriate for them, which shall include full homogeneous and partial load conditions and partial filling to any intermediate levels; and

.2 being appropriate for uncertainties in loads, structural modelling, fatigue, corrosion, thermal effects, material variability, aging and construction tolerances.

LR 6.4-02 Except as otherwise mentioned, the suitable safety margin is to be considered as 2,0. A lower safety margin may be proposed, provided that a technical justification is submitted and justified.

6.4.1.6 The liquefied gas fuel containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue. The specific design conditions that shall be considered for the design of each liquefied gas fuel containment system are given in 6.4.15. There are three main categories of design conditions:

.1 Ultimate Design Conditions – The liquefied gas fuel containment system structure and its structural components shall withstand loads liable to occur during its construction, testing and anticipated use in service, without loss of structural integrity. The design shall take into account proper combinations of the following loads:

- .1 internal pressure;
- .2 external pressure;
- .3 dynamic loads due to the motion of the ship in all loading conditions;
- .4 thermal loads;
- .5 sloshing loads;
- .6 loads corresponding to ship deflections;
- .7 tank and liquefied gas fuel weight with the corresponding reaction in way of supports;
- .8 insulation weight;
- .9 loads in way of towers and other attachments; and
- .10 test loads.

.2 Fatigue Design Conditions – The liquefied gas fuel containment system structure and its structural components shall not fail under accumulated cyclic loading.

LR.6.4-03 Unless it can be demonstrated that partial fill conditions have a negligible contribution to fatigue life, loading conditions to be considered for fatigue design need to include partial fill conditions selected to maximise the dynamic load on internal tank members, including sloshing induced loads, *see also* 6.4.9.4.1.3 and 6.4.12.2.3.

[7] Refer to IACS Rec.034.

[8] North Atlantic environmental conditions refer to wave conditions. Assumed temperatures are used for determining appropriate material qualities with respect to design temperatures and is another matter not intended to be covered in 6.4.1.4.

.3 Accidental Design Conditions – The liquefied gas fuel containment system shall meet each of the following accident design conditions (accidental or abnormal events), addressed in this Code:

.1 Collision – The liquefied gas fuel containment system shall withstand the collision loads specified in 6.4.9.5.1 without deformation of the supports or the tank structure in way of the supports likely to endanger the tank and its supporting structure.

.2 Fire – The liquefied gas fuel containment systems shall sustain without rupture the rise in internal pressure specified in 6.7.3.1 under the fire scenarios envisaged therein.

.3 Flooded compartment causing buoyancy on tank – the anti-flotation arrangements shall sustain the upward force, specified in 6.4.9.5.2 and there shall be no endangering plastic deformation to the hull. Plastic deformation may occur in the fuel containment system provided it does not endanger the safe evacuation of the ship.

6.4.1.7 Measures shall be applied to ensure that scantlings required meet the structural strength provisions and are maintained throughout the design life. Measures may include, but are not limited to, material selection, coatings, corrosion additions, cathodic protection and inerting.

6.4.1.8 An inspection/survey plan for the liquefied gas fuel containment system shall be developed and approved by the Administration. The inspection/survey plan shall identify aspects to be examined and/or validated during surveys throughout the liquefied gas fuel containment system's life and, in particular, any necessary in-service survey, maintenance and testing that was assumed when selecting liquefied gas fuel containment system design parameters. The inspection/survey plan may include specific critical locations as per 6.4.12.2.8 or 6.4.12.2.9.

LR 6.4-04 Due consideration is to be given to the design parameters and construction of the fuel containment system, when developing the inspection/survey plan of the fuel containment system.

6.4.1.9 Liquefied gas fuel containment systems shall be designed, constructed and equipped to provide adequate means of access to areas that need inspection as specified in the inspection/survey plan. Liquefied gas fuel containment systems, including all associated internal equipment shall be designed and built to ensure safety during operations, inspection and maintenance.

6.4.2 Liquefied gas fuel containment safety principles

6.4.2.1 The containment systems shall be provided with a complete secondary liquid-tight barrier capable of safely containing all potential leakages through the primary barrier and, in conjunction with the thermal insulation system, of preventing lowering of the temperature of the ship structure to an unsafe level.

6.4.2.2 The size and configuration or arrangement of the secondary barrier may be reduced or omitted where an equivalent level of safety can be demonstrated in accordance with 6.4.2.3 to 6.4.2.5 as applicable.

6.4.2.3 Liquefied gas fuel containment systems for which the probability for structural failures to develop into a critical state has been determined to be extremely low but where the possibility of leakages through the primary barrier cannot be excluded, shall be equipped with a partial secondary barrier and small leak protection system capable of safely handling and disposing of the leakages (a critical state means that the crack develops into unstable condition).

The arrangements shall comply with the following:

.1 failure developments that can be reliably detected before reaching a critical state (e.g. by gas detection or inspection) shall have a sufficiently long development time for remedial actions to be taken; and

.2 failure developments that cannot be safely detected before reaching a critical state shall have a predicted development time that is much longer than the expected lifetime of the tank.

6.4.2.4 No secondary barrier is required for liquefied gas fuel containment systems, e.g. type C independent tanks, where the probability for structural failures and leakages through the primary barrier is extremely low and can be neglected.

6.4.2.5 For independent tanks requiring full or partial secondary barrier, means for safely disposing of leakages from the tank shall be arranged.

6.4.3 Secondary barriers in relation to tank types

Secondary barriers in relation to the tank types defined in 6.4.15 shall be provided in accordance with the following table.

Basic tank type	Secondary barrier requirements
Membrane	Complete secondary barrier
Independent	

Type A	Complete secondary barrier
Type B	Partial secondary barrier
Type C	No secondary barrier required

6.4.4 Design of secondary barriers

The design of the secondary barrier, including spray shield if fitted, shall be such that:

.1 it is capable of containing any envisaged leakage of liquefied gas fuel for a period of 15 days unless different criteria apply for particular voyages, taking into account the load spectrum referred to in 6.4.12.2.6;

.2 physical, mechanical or operational events within the liquefied gas fuel tank that could cause failure of the primary barrier shall not impair the due function of the secondary barrier, or vice versa;

.3 failure of a support or an attachment to the hull structure will not lead to loss of liquid tightness of both the primary and secondary barriers;

.4 it is capable of being periodically checked for its effectiveness by means of a visual inspection or other suitable means acceptable to the Administration;

.

5 the methods required in 6.4.4.4 shall be approved by the Administration and shall include, as a minimum:

.1 details on the size of defect acceptable and the location within the secondary barrier, before its liquid tight effectiveness is compromised;

.2 accuracy and range of values of the proposed method for detecting defects in .1 above;

.3 scaling factors to be used in determining the acceptance criteria if full-scale model testing is not undertaken; and

.4 effects of thermal and mechanical cyclic loading on the effectiveness of the proposed test.

.6 the secondary barrier shall fulfil its functional requirements at a static angle of heel of 30°.

6.4.5 Partial secondary barriers and primary barrier small leak protection system

6.4.5.1 Partial secondary barriers as permitted in 6.4.2.3 shall be used with a small leak protection system and meet all the regulations in 6.4.4.

The small leak protection system shall include means to detect a leak in the primary barrier, provision such as a spray shield to deflect any liquefied gas fuel down into the partial secondary barrier, and means to dispose of the liquid, which may be by natural evaporation.

6.4.5.2 The capacity of the partial secondary barrier shall be determined, based on the liquefied gas fuel leakage corresponding to the extent of failure resulting from the load spectrum referred to in 6.4.12.2.6, after the initial detection of a primary leak. Due account may be taken of liquid evaporation, rate of leakage, pumping capacity and other relevant factors.

6.4.5.3 The required liquid leakage detection may be by means of liquid sensors, or by an effective use of pressure, temperature or gas detection systems, or any combination thereof.

6.4.5.4 For independent tanks for which the geometry does not present obvious locations for leakage to collect, the partial secondary barrier shall also fulfil its functional requirements at a nominal static angle of trim.

6.4.6 Supporting arrangements

6.4.6.1 The liquefied gas fuel tanks shall be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in 6.4.9.2 to 6.4.9.5, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

6.4.6.2 Anti-flotation arrangements shall be provided for independent tanks and capable of withstanding the loads defined in 6.4.9.5.2 without plastic deformation likely to endanger the hull structure.

LR 6.4-05 An adequate clearance is to be provided between the anti-flotation chocks and the ship's hull in all operational conditions. Details of the calculations of the clearances between anti-flotation chocks are to be submitted for approval. The inspection/survey plan indicated in 6.4.1.8 is to include details for the verification of these clearances during construction and periodical surveys.

6.4.6.3 Supports and supporting arrangements shall withstand the loads defined in 6.4.9.3.3.8 and 6.4.9.5, but these loads need not be combined with each other or with wave-induced loads.

LR 6.4-06 Tank supports are generally to be located in way of the primary support structure of the tank and the ship's hull. Steel seatings are to be arranged, so as to ensure an effective distribution of the transmitted load and reactions into the fuel tank and the supporting structure.

LR 6.4-07 Where deemed necessary by LR and depending upon the type and size of the fuel tank(s), the strength of the supporting arrangements may be required to be verified by direct calculations.

6.4.7 Associated structure and equipment

6.4.7.1 Liquefied gas fuel containment systems shall be designed for the loads imposed by associated structure and equipment. This includes pump towers, liquefied gas fuel domes, liquefied gas fuel pumps and piping, stripping pumps and piping, nitrogen piping, access hatches, ladders, piping penetrations, liquid level gauges, independent level alarm gauges, spray nozzles, and instrumentation systems (such as pressure, temperature and strain gauges).

6.4.8 Thermal insulation

6.4.8.1 Thermal insulation shall be provided as required to protect the hull from temperatures below those allowable (see 6.4.13.1.1) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in 6.9.

LR 6.4-08 Thermal insulation shall also comply with the requirements of 6.4.13.3.

6.4.9 Design loads

6.4.9.1 *General*

6.4.9.1.1 This section defines the design loads that shall be considered with regard to regulations in 6.4.10 to 6.4.12. This includes load categories (permanent, functional, environmental and accidental) and the description of the loads.

6.4.9.1.2 The extent to which these loads shall be considered depends on the type of tank, and is more fully detailed in the following paragraphs.

6.4.9.1.3 Tanks, together with their supporting structure and other fixtures, shall be designed taking into account relevant combinations of the loads described below.

6.4.9.2 *Permanent loads*

6.4.9.2.1 Gravity loads

The weight of tank, thermal insulation, loads caused by towers and other attachments shall be considered.

6.4.9.2.2 Permanent external loads

Gravity loads of structures and equipment acting externally on the tank shall be considered.

6.4.9.3 Functional loads

6.4.9.3.1 Loads arising from the operational use of the tank system shall be classified as functional loads.

6.4.9.3.2 All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, shall be considered.

6.4.9.3.3 As a minimum, the effects from the following criteria, as applicable, shall be considered when establishing functional loads:

(a) internal pressure
(b) external pressure
(c) thermally induced loads
(d) vibration
(e) interaction loads
(f) loads associated with construction and installation
(g) test loads
(h) static heel loads
(i) weight of liquefied gas fuel
(j) sloshing
(k) wind impact, wave impacts and green sea effect for tanks installed on open deck.

6.4.9.3.3.1 Internal pressure

.1 In all cases, including 6.4.9.3.3.1.2, P_0 shall not be less than MARVS.

.2 For liquefied gas fuel tanks where there is no temperature control and where the pressure of the liquefied gas fuel is dictated only by the ambient temperature, P_0 shall not be less than the gauge vapour pressure of the liquefied gas fuel at a temperature of 45°C except as follows:

.1 Lower values of ambient temperature may be accepted by the Administration for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.

.2 For ships on voyages of restricted duration, P_0 may be calculated based on the actual pressure rise during the voyage and account may be taken of any thermal insulation of the tank.

LR 6.4-09 Consideration will be given to the use of a higher or lower ambient temperature where appropriate. In such cases, the temperature which has been used will be included in the class notation.

.3 Subject to special consideration by the Administration and to the limitations given in 6.4.15 for the various tank types, a vapour pressure P_h higher than P_0 may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced.

LR 6.4-10 Where a vapour pressure, P_h, higher than P_o, is accepted in accordance with 6.4.9.3.3.1.3, such conditions are to be clearly indicated in the ship's Loading Manual.

.4 Pressure used for determining the internal pressure shall be:

.1 $(P_{gd})max$ is the associated liquid pressure determined using the maximum design accelerations.

.2 $(P_{gd\ site})max$ is the associated liquid pressure determined using site specific accelerations.

.3 P_{eq} should be the greater of P_{eq1} and P_{eq2} calculated as follows:

$P_{eq1} = P_0 + (P_{gd})max$ (MPa),

$P_{eq2} = P_h + (P_{gd\ site})max$ (MPa).

.5 The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the liquefied gas fuel due to the motions of the ship referred to in 6.4.9.4.1.1. The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations shall be calculated as follows:

$P_{gd} = \alpha_\beta Z_\beta (\rho/(1.02 \times 10^5))$ (MPa)

where:

α_β = dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction β; (see figure 6.4.1).

For large tanks, an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations, should be used.

Z_β = largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the β direction (see figure 6.4.2).

Tank domes considered to be part of the accepted total tank volume shall be taken into account when determining Z_β unless the total volume of tank domes V_d does not exceed the following value:

$$V_d = V_t\left(\frac{100 - FL}{FL}\right)$$

where:

V_t = tank volume without any domes; and

FL = filling limit according to 6.8.

ρ = maximum liquefied gas fuel density (kg/m^3) at the design temperature.

The direction that gives the maximum value $(P_{gd})max$ or $(P_{gd\ site})max$ shall be considered. Where acceleration components in three directions need to be considered, an ellipsoid shall be used instead of the ellipse in figure 6.4.1. The above formula applies only to full tanks.

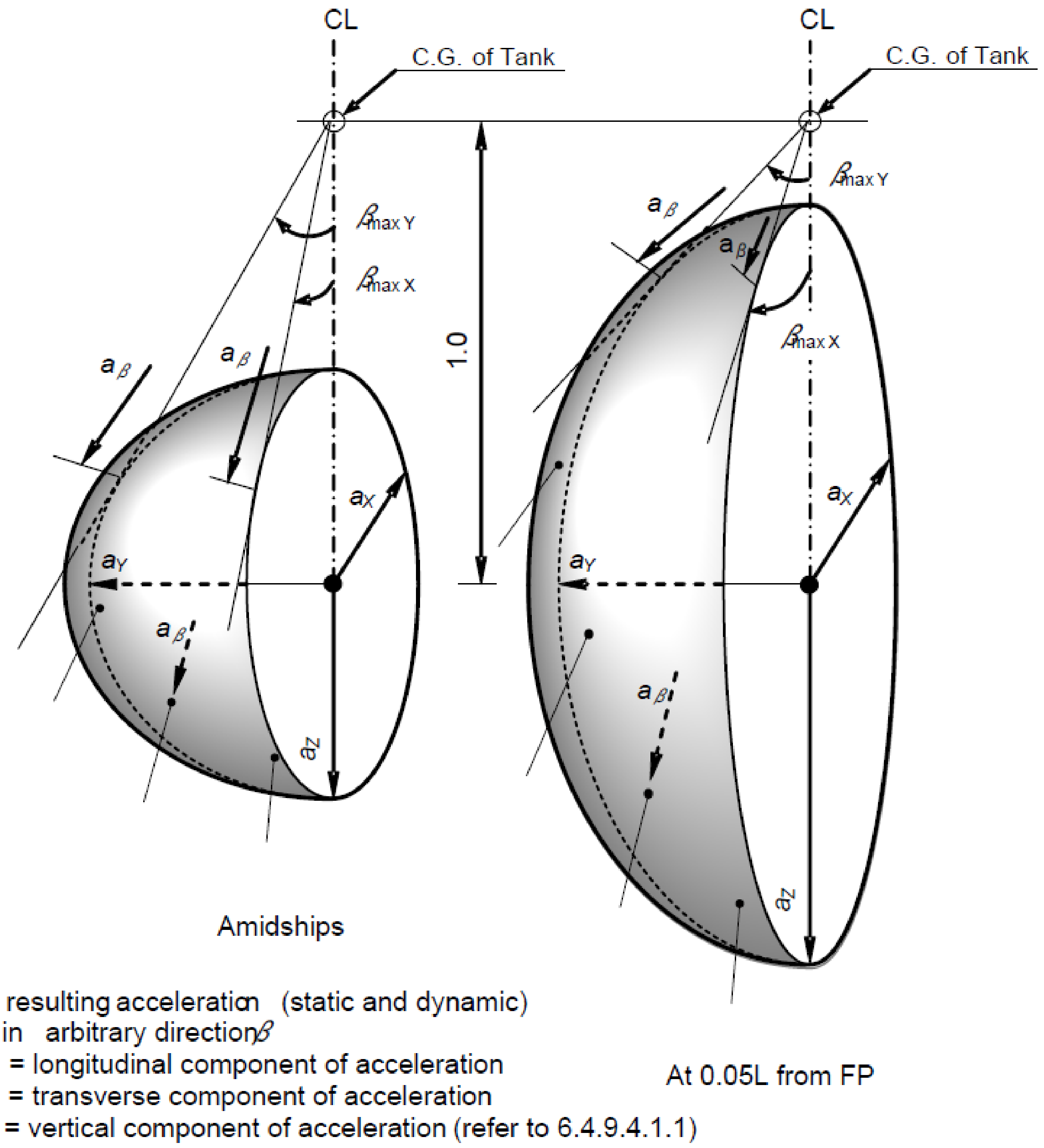

Figure 6.4.1 – Acceleration ellipsoid

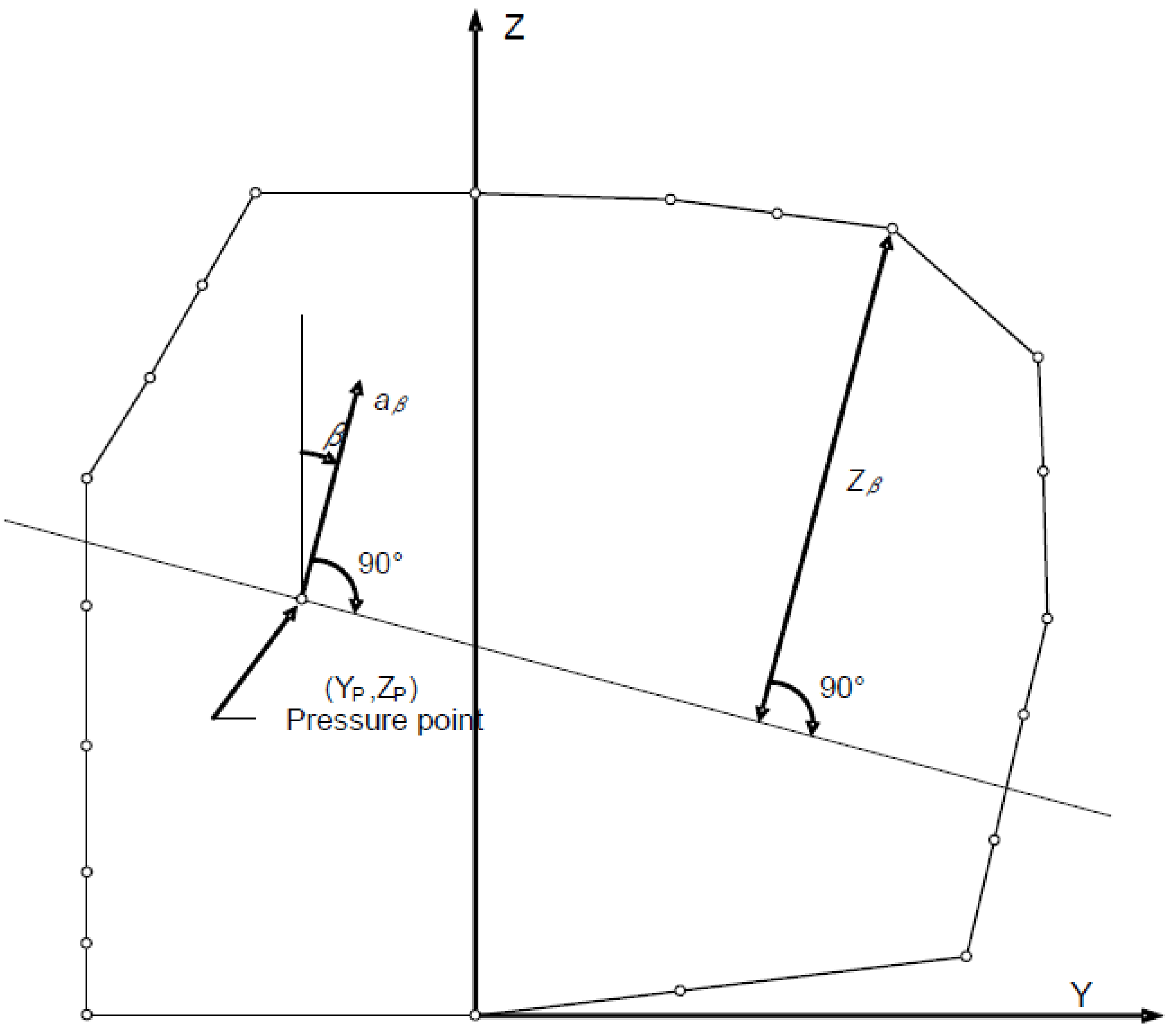

Figure 6.4.2 – Determination of internal pressure heads

6.4.9.3.3.2 External pressure

External design pressure loads shall be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

6.4.9.3.3.3 Thermally induced loads

6.4.9.3.3.3.1 Transient thermally induced loads during cooling down periods shall be considered for tanks intended for liquefied gas fuel temperatures below minus 55°C.

6.4.9.3.3.3.2 Stationary thermally induced loads shall be considered for liquefied gas fuel containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (see paragraph 6.9.2).

6.4.9.3.3.4 Vibration

The potentially damaging effects of vibration on the liquefied gas fuel containment system shall be considered.

LR 6.4-11 Vibration analysis of the pump tower is to be carried out where appropriate, i.e. considering the dimensions of the containment system in accordance with LR's *ShipRight Procedure Additional Design Procedures - Procedure for Analysis of pump tower and pump tower base*. The designer may propose an alternative equivalent procedure subject to agreement with LR.

6.4.9.3.3.5 Interaction loads

The static component of loads resulting from interaction between liquefied gas fuel containment system and the hull structure, as well as loads from associated structure and equipment, shall be considered.

6.4.9.3.3.6 Loads associated with construction and installation

Loads or conditions associated with construction and installation shall be considered, e.g. lifting.

6.4.9.3.3.7 Test loads

Account shall be taken of the loads corresponding to the testing of the liquefied gas fuel containment system referred to in 16.5.

6.4.9.3.3.8 Static heel loads

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30°shall be considered.

6.4.9.3.3.9 Other loads

Any other loads not specifically addressed, which could have an effect on the liquefied gas fuel containment system, shall be taken into account.

6.4.9.4 Environmental loads

6.4.9.4.1 Environmental loads are defined as those loads on the liquefied gas fuel containment system that are caused by the surrounding environment and that are not otherwise classified as a permanent, functional or accidental load.

6.4.9.4.1.1 Loads due to ship motion

The determination of dynamic loads shall take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading. The ship's motion shall include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks shall be estimated at their centre of gravity and include the following components:

.1 vertical acceleration: motion accelerations of heave, pitch and, possibly roll (normal to the ship base);

.2 transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll; and

.3 longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

Methods to predict accelerations due to ship motion shall be proposed and approved by the Administration[9].

Ships for restricted service may be given special consideration.

LR 6.4-12 Direct calculation procedures capable of deriving the dynamic loads due to ship motions, are to take into account the ship’s actual form and weight distribution. LR’s direct calculation method involves derivation of response to regular waves by appropriate sea-keeping software, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are expected to contain these three elements and produce similar and consistent results when compared with LR’s method. Simplified dynamic loading spectra, where proposed, are to be submitted for consideration.

6.4.9.4.1.2 Dynamic interaction loads

Account shall be taken of the dynamic component of loads resulting from interaction between liquefied gas fuel containment systems and the hull structure, including loads from associated structures and equipment.

6.4.9.4.1.3 Sloshing loads

The sloshing loads on a liquefied gas fuel containment system and internal components shall be evaluated for the full range of intended filling levels.

LR 6.4-13 Where loading conditions are proposed including one or more partially filled tanks, calculations or model tests will be required to show that the resulting loads and pressure are within acceptable limits for the scantlings of the tanks. In general, calculations are to be carried out in accordance with LR’s *ShipRight Procedure Design and Construction Procedure, Structural Design Assessment, Sloshing Loads and Scantling Assessment*. Alternative procedures may be specially considered.

[9] Refer to section 4.28.2.1 of the IGC Code for guidance formulae for acceleration components.

LR 6.4-14 Investigations to ensure that the internal structure, equipment and pipework exposed to fluid motion are of adequate strength are also to be carried out. The assessment of pump tower and pump tower base due to fluid motion is in general to be carried out in accordance with LR's *ShipRight Procedure Additional Design Procedures, Procedure for Analysis of Pump Tower and Pump Tower Base*.

6.4.9.4.1.4 Snow and ice loads

Snow and icing shall be considered, if relevant.

LR 6.4-15 Where a vessel is intended to operate in cold climates, the temperature on exposed surfaces is to be considered. *See* the *Rules for the Winterisation of Ships*.

6.4.9.4.1.5 Loads due to navigation in ice

Loads due to navigation in ice shall be considered for ships intended for such service.

LR 6.4-16 Where a vessel is intended to navigate through ice, the vessel's interaction with ice is to be considered. *See* Pt 8 of the Rules for Ships.

6.4.9.4.1.6 Green sea loading

Account shall be taken to loads due to water on deck.

6.4.9.4.1.7 Wind loads

Account shall be taken to wind generated loads as relevant.

6.4.9.5 *Accidental loads*

Accidental loads are defined as loads that are imposed on a liquefied gas fuel containment system and it's supporting arrangements under abnormal and unplanned conditions.

6.4.9.5.1 Collision load

The collision load shall be determined based on the fuel containment system under fully loaded condition with an inertial force corresponding to "a" in the table below in forward direction and "a/2" in the aft direction, where "g" is gravitational acceleration.

Ship length (L)	Design acceleration (a)
L > 100 m	0,5 g
60 < L ≤ 100 m	$2-\left(\frac{3(L-60)}{80}\right)g$
L ≤ 60 m	2g

Special consideration should be given to ships with Froude number (Fn) > 0,4.

6.4.9.5.2 Loads due to flooding on ship

For independent tanks, loads caused by the buoyancy of a fully submerged empty tank shall be considered in the design of anti-flotation chocks and the supporting structure in both the adjacent hull and tank structure.

LR 6.4-17 Subject to agreement by the National Administration, anti-flotation chocks and supporting structure may be designed based on the tank being empty and submerged up to the damaged water line obtained when the tank compartment is flooded, or the scantling draft, whichever is deeper.

6.4.10 Structural integrity

6.4.10.1 General

6.4.10.1.1 The structural design shall ensure that tanks have an adequate capacity to sustain all relevant loads with an adequate margin of safety. This shall take into account the possibility of plastic deformation, buckling, fatigue and loss of liquid and gas tightness.

6.4.10.1.2 The structural integrity of liquefied gas fuel containment systems can be demonstrated by compliance with 6.4.15, as appropriate for the liquefied gas fuel containment system type.

6.4.10.1.3 For other liquefied gas fuel containment system types, that are of novel design or differ significantly from those covered by 6.4.15, the structural integrity shall be demonstrated by compliance with 6.4.16.

6.4.11 Structural analysis

6.4.11.1 *Analysis*

6.4.11.1.1 The design analyses shall be based on accepted principles of statics, dynamics and strength of materials.

6.4.11.1.2 Simplified methods or simplified analyses may be used to calculate the load effects, provided that they are conservative. Model tests may be used in combination with, or instead of, theoretical calculations. In cases where theoretical methods are inadequate, model or full-scale tests may be required.

LR 6.4-18 Where simplified methods or simplified analyses are proposed, their details are to be agreed with LR before commencement of application.

6.4.11.1.3 When determining responses to dynamic loads, the dynamic effect shall be taken into account where it may affect structural integrity.

6.4.11.2 *Load scenarios*

6.4.11.2.1 For each location or part of the liquefied gas fuel containment system to be considered and for each possible mode of failure to be analysed, all relevant combinations of loads that may act simultaneously shall be considered.

LR 6.4-19 LR is to be consulted for guidance on the relevant combination of loads to be taken into account in the analysis at as early a stage as possible.

6.4.11.2.2 The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service conditions shall be considered.

6.4.11.2.3 When the static and dynamic stresses are calculated separately and unless other methods of calculation are justified, the total stresses shall be calculated according to:

$$\sigma_x = \sigma_{x.st} \pm \sqrt{\Sigma\left(\sigma_{x.dyn}\right)^2}$$
$$\sigma_y = \sigma_{y.st} \pm \sqrt{\Sigma\left(\sigma_{y.dyn}\right)^2}$$
$$\sigma_z = \sigma_{z.st} \pm \sqrt{\Sigma\left(\sigma_{z.dyn}\right)^2}$$
$$\tau_{xy} = \tau_{xy.st} \pm \sqrt{\Sigma\left(\tau_{xy.dyn}\right)^2}$$
$$\tau_{xz} = \tau_{xz.st} \pm \sqrt{\Sigma\left(\tau_{xz.dyn}\right)^2}$$
$$\tau_{yz} = \tau_{yz.st} \pm \sqrt{\Sigma\left(\tau_{yz.dyn}\right)^2}$$

where:

$\sigma_{x.st}$, $\sigma_{y.st}$, $\sigma_{z.st}$, $\tau_{xy.st}$, $\tau_{xz.st}$ and $\tau_{yz.st}$ are static stresses; and

$\sigma_{x.dyn}$, $\sigma_{y.dyn}$, $\sigma_{z.dyn}$, $\tau_{xy.dyn}$, $\tau_{xz.dyn}$ and $\tau_{yz.dyn}$ are dynamic stresses,

each shall be determined separately from acceleration components and hull strain components due to deflection and torsion.

6.4.12 Design conditions

All relevant failure modes shall be considered in the design for all relevant load scenarios and design conditions. The design conditions are given in the earlier part of this chapter, and the load scenarios are covered by 6.4.11.2.

6.4.12.1 *Ultimate design condition*

6.4.12.1.1 Structural capacity may be determined by testing, or by analysis, taking into account both the elastic and plastic material properties, by simplified linear elastic analysis or by the provisions of this Code:

.1 Plastic deformation and buckling shall be considered.

LR 6.4-20 Plastic deformation analyses is to be conducted in accordance with an agreed recognised Standard.

.2 Analysis shall be based on characteristic load values as follows:

Permanent loads	Expected values
Functional loads	Specified values
Environmental loads	For wave loads: most probable largest load encountered during 10^8 wave encounters.

.3 For the purpose of ultimate strength assessment the following material parameters apply:

.1 R_e = specified minimum yield stress at room temperature (N/mm^2). If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

.2 R_m = specified minimum tensile strength at room temperature (N/mm^2).

For welded connections where under-matched welds, i.e. where the weld metal has lower tensile strength than the parent metal, are unavoidable, such as in some aluminium alloys, the respective R_e and R_m of the welds, after any applied heat treatment, shall be used. In such cases the transverse weld tensile strength shall not be less than the actual yield strength of the parent metal. If this cannot be achieved, welded structures made from such materials shall not be incorporated in liquefied gas fuel containment systems.

The above properties shall correspond to the minimum specified mechanical properties of the material, including the weld metal in the as fabricated condition. Subject to special consideration by the Administration, account may be taken of the enhanced yield stress and tensile strength at low temperature.

.4 The equivalent stress σ_c (von Mises, Huber) shall be determined by:

$$\sigma_c = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x\sigma_y - \sigma_x\sigma_z - \sigma_y\sigma_z + 3\left(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2\right)}$$

where:

σ_x = total normal stress in x-direction;
σ_y = total normal stress in y-direction;
σ_z = total normal stress in z-direction;
τ_{xy} = total shear stress in x-y plane;
τ_{xz} = total shear stress in x-z plane; and
τ_{yz} = total shear stress in y-z plane.

The above values shall be calculated as described in 6.4.11.2.3.

.5 Allowable stresses for materials other than those covered by 7.4 shall be subject to approval by the Administration in each case.

LR 6.4-21 For materials other than those covered by Ch 7, details of the allowable stresses are to be submitted for consideration.

.6 Stresses may be further limited by fatigue analysis, crack propagation analysis and buckling criteria.

6.4.12.2 *Fatigue Design Condition*

.1 The fatigue design condition is the design condition with respect to accumulated cyclic loading.

.2 Where a fatigue analysis is required the cumulative effect of the fatigue load shall comply with:

$$\Sigma\frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \leq C_w$$

where:

n_i = number of stress cycles at each stress level during the life of the tank;

N_i = *number of cycles to fracture for the respective stress level according to the Wohler (S-N) curve;*

$n_{Loading}$ = number of loading and unloading cycles during the life of the tank not to be less than 1000. Loading and unloading cycles include a complete pressure and thermal cycle;

$N_{Loading}$ = number of cycles to fracture for the fatigue loads due to loading and unloading; and

C_w = maximum allowable cumulative fatigue damage ratio.

The fatigue damage shall be based on the design life of the tank but not less than 10^8 wave encounters.

.3 Where required, the liquefied gas fuel containment system shall be subject to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the liquefied gas fuel containment system. Consideration shall be given to various filling conditions.

.4 Design S-N curves used in the analysis shall be applicable to the materials and weldments, construction details, fabrication procedures and applicable state of the stress envisioned.

The S-N curves shall be based on a 97.6% probability of survival corresponding to the mean-minus-two-standard-deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different way requires adjustments to the acceptable Cw values specified in 6.4.12.2.7 to 6.4.12.2.9.

.5 Analysis shall be based on characteristic load values as follows:

Permanent loads	Expected values
Functional loads	Specified values or specified history
Environmental loads	Expected load history, but not less than 10^8 cycles

If simplified dynamic loading spectra are used for the estimation of the fatigue life, those shall be specially considered by the Administration.

.6 Where the size of the secondary barrier is reduced, as is provided for in 6.4.2.3, fracture mechanics analyses of fatigue crack growth shall be carried out to determine:

.1 crack propagation paths in the structure, where necessitated by 6.4.12.2.7 to 6.4.12.2.9, as applicable;

.2 crack growth rate;

.3 the time required for a crack to propagate to cause a leakage from the tank;

.4 the size and shape of through thickness cracks; and

.5 the time required for detectable cracks to reach a critical state after penetration through the thickness.

The fracture mechanics are in general based on crack growth data taken as a mean value plus two standard deviations of the test data. Methods for fatigue crack growth analysis and fracture mechanics shall be based on recognized standards.

In analysing crack propagation the largest initial crack not detectable by the inspection method applied shall be assumed, taking into account the allowable non-destructive testing and visual inspection criterion as applicable.

Crack propagation analysis specified in 6.4.12.2.7 the simplified load distribution and sequence over a period of 15 days may be used. Such distributions may be obtained as indicated in figure 6.4.3. Load distribution and sequence for longer periods, such as in 6.4.12.2.8 and 6.4.12.2.9 shall be approved by the Administration.

The arrangements shall comply with 6.4.12.2.7 to 6.4.12.2.9 as applicable.

.7 For failures that can be reliably detected by means of leakage detection:

C_w shall be less than or equal to 0.5.

Predicted remaining failure development time, from the point of detection of leakage till reaching a critical state, shall not be less than 15 days unless different regulations apply for ships engaged in particular voyages.

.

8 For failures that cannot be detected by leakage but that can be reliably detected at the time of in-service inspections:

C_w shall be less than or equal to 0.5.

Predicted remaining failure development time, from the largest crack not detectable by in-service inspection methods until reaching a critical state, shall not be less than three (3) times the inspection interval.

.9 In particular locations of the tank where effective defect or crack development detection cannot be assured, the following, more stringent, fatigue acceptance criteria shall be applied as a minimum:

C_w shall be less than or equal to 0.1.

Predicted failure development time, from the assumed initial defect until reaching a critical state, shall not be less than three (3) times the lifetime of the tank.

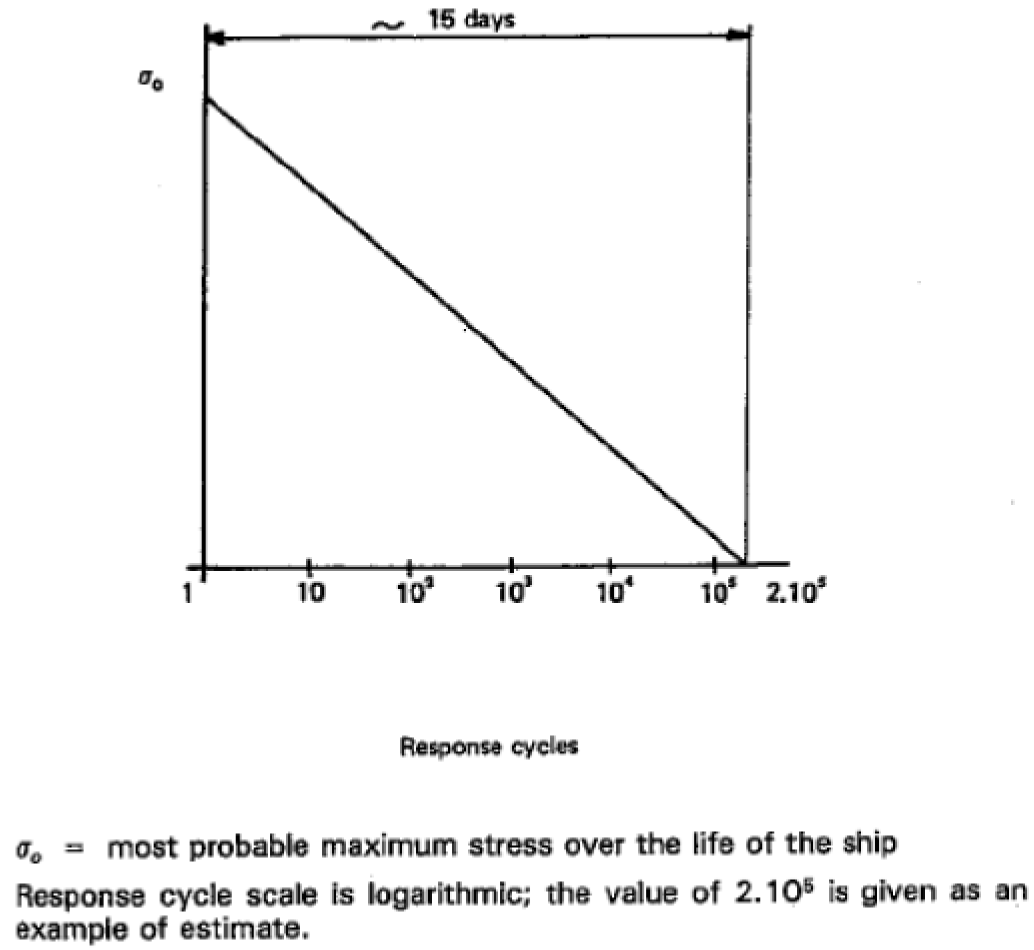

Figure 6.4.3 – Simplified load distribution

6.4.12.3 *Accidental design condition*

6.4.12.3.1 The accidental design condition is a design condition for accidental loads with extremely low probability of occurrence.

6.4.12.3.2 Analysis shall be based on the characteristic values as follows:

Permanent loads	Expected values
Functional loads	Specified values
Environmental loads	Specified values
Accidental loads	Specified values or expected values

Loads mentioned in 6.4.9.3.3.8 and 6.4.9.5 need not be combined with each other or with wave-induced loads.

6.4.13 Materials and construction

6.4.13.1 Materials

6.4.13.1.1 Materials forming ship structure

6.4.13.1.1.1 To determine the grade of plate and sections used in the hull structure, a temperature calculation shall be performed for all tank types. The following assumptions shall be made in this calculation:

.1 The primary barrier of all tanks shall be assumed to be at the liquefied gas fuel temperature.

.2 In addition to .1 above, where a complete or partial secondary barrier is required it shall be assumed to be at the liquefied gas fuel temperature at atmospheric pressure for any one tank only.

.3 For worldwide service, ambient temperatures shall be taken as 5°C for air and 0°C for seawater. Higher values may be accepted for ships operating in restricted areas and conversely, lower values may be imposed by the Administration for ships trading to areas where lower temperatures are expected during the winter months.

.4 Still air and sea water conditions shall be assumed, i.e. no adjustment for forced convection.

.5 Degradation of the thermal insulation properties over the life of the ship due to factors such as thermal and mechanical ageing, compaction, ship motions and tank vibrations as defined in 6.4.13.3.6 and 6.4.13.3.7 shall be assumed.

.6 The cooling effect of the rising boil-off vapour from the leaked liquefied gas fuel shall be taken into account where applicable.

.7 Credit for hull heating may be taken in accordance with 6.4.13.1.1.3, provided the heating arrangements are in compliance with 6.4.13.1.1.4.

.8 No credit shall be given for any means of heating, except as described in 6.4.13.1.1.3.

.9 For members connecting inner and outer hulls, the mean temperature may be taken for determining the steel grade.

LR 6.4-22 The minimum temperatures used in determining the required grade of materials are to be calculated using the boundary conditions given in 6.4.13.1.1.1. Where a higher or lower ambient temperature is to be used in accordance with 6.4.13.1.1.1.3, this is to be included in the class notation. The revised ambient temperatures are to be considered when determining the required hull material grades, both within and outside the cargo area.

LR 6.4-23 The temperatures of members connecting the inner and outer hulls where applicable are to be obtained from the calculations.

LR 6.4-24 The heat balance method may be used to carry out the temperature calculations required in 6.4.13.1.1.1.

6.4.13.1.1.2 The materials of all hull structures for which the calculated temperature in the design condition is below 0°C, due to the influence of liquefied gas fuel temperature, shall be in accordance with table 7.5. This includes hull structure supporting the liquefied gas fuel tanks, inner bottom plating, longitudinal bulkhead plating, transverse bulkhead plating, floors, webs, stringers and all attached stiffening members.

LR 6.4-25 The material of the hull structure, other than that forming part of, or adjoining, the fuel containment system, is to comply with the requirements given in LR 7.4-02 and subsequent paragraphs.

6.4.13.1.1.3 Means of heating structural materials may be used to ensure that the material temperature does not fall below the minimum allowed for the grade of material specified in table 7.5. In the calculations required in 6.4.13.1.1.1, credit for such heating may be taken in accordance with the following principles:

.1 for any transverse hull structure;

.2 for longitudinal hull structure referred to in 6.4.13.1.1.2 where colder ambient temperatures are specified, provided the material remains suitable for the ambient temperature conditions of plus 5°C for air and 0°C for seawater with no credit taken in the calculations for heating; and

.3 as an alternative to 6.4.13.1.1.3.2, for longitudinal bulkhead between liquefied gas fuel tanks, credit may be taken for heating provided the material remain suitable for a minimum design temperature of minus 30°C, or a temperature 30°C lower than that determined by 6.4.13.1.1.1 with the heating considered, whichever is less. In this case, the ship's longitudinal strength shall comply with *SOLAS regulation II-1/3-1* for both when those bulkhead(s) are considered effective and not.

LR 6.4-26 Details of proposed systems for the means of heating structural members to ensure that the material temperature does not fall below the minimum temperature allowed for the grade of material specified in Table 7.5 are to be submitted.

6.4.13.1.1.4 The means of heating referred to in 6.4.13.1.1.3 shall comply with the following:

.1 the heating system shall be arranged so that, in the event of failure in any part of the system, standby heating can be maintained equal to no less than 100% of the theoretical heat requirement;

.2 the heating system shall be considered as an essential auxiliary. All electrical components of at least one of the systems provided in accordance with 6.4.13.1.1.3.1 shall be supplied from the emergency source of electrical power; and

.3 the design and construction of the heating system shall be included in the approval of the containment system by the Administration.

6.4.13.2 Materials of primary and secondary barriers

LR 6.4-27 The specification and plans of the fuel containment system, including the insulation, are to be submitted for approval. The materials used are to be approved by LR.

6.4.13.2.1 Metallic materials used in the construction of primary and secondary barriers not forming the hull, shall be suitable for the design loads that they may be subjected to, and be in accordance with table 7.1, 7.2 or 7.3.

6.4.13.2.2 Materials, either non-metallic or metallic but not covered by tables 7.1, 7.2 and 7.3, used in the primary and secondary barriers may be approved by the Administration considering the design loads that they may be subjected to, their properties and their intended use.

6.4.13.2.3 Where non-metallic materials,[10] including composites, are used for or incorporated in the primary or secondary barriers, they shall be tested for the following properties, as applicable, to ensure that they are adequate for the intended service:

.1 compatibility with the liquefied gas fuels;
.2 ageing;
.3 mechanical properties;
.4 thermal expansion and contraction;
.5 abrasion;
.6 cohesion;
.7 resistance to vibrations;
.8 resistance to fire and flame spread; and
.9 resistance to fatigue failure and crack propagation.

LR 6.4-28 Guidance on the use of non-metallic materials in the construction of primary and secondary barriers is provided in Appendix 4 of Rules for Ships for Liquefied Gases.

LR 6.4-29 Details of the extent of ageing of the insulation material used in the fuel containment system are to be submitted to LR for consideration.

6.4.13.2.4 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than minus196°C.

LR 6.4-30 In addition to the requirements given in 6.4.13.2.3, fatigue and crack propagation properties for insulation in membrane systems are also to be submitted. Insulation materials are to be approved by LR. Where applicable, these requirements also apply to any adhesive, sealers, vapour barriers, coatings or similar products used in the insulation system, any material used to give strength to the insulation system, components used to hold the insulation in place and any non-metallic membrane materials. Such products are to be compatible with the insulation.

6.4.13.2.5 Where non-metallic materials, including composites, are used for the primary and secondary barriers, the joining processes shall also be tested as described above.

6.4.13.2.6 Consideration may be given to the use of materials in the primary and secondary barrier, which are not resistant to fire and flame spread, provided they are protected by a suitable system such as a permanent inert gas environment, or are provided with a fire retardant barrier.

6.4.13.3 Thermal insulation and other materials used in liquefied gas fuel containment systems

6.4.13.3.1 Load-bearing thermal insulation and other materials used in liquefied gas fuel containment systems shall be suitable for the design loads.

6.4.13.3.2 Thermal insulation and other materials used in liquefied gas fuel containment systems shall have the following properties, as applicable, to ensure that they are adequate for the intended service:

.1 compatibility with the liquefied gas fuels;
.2 solubility in the liquefied gas fuel;
.3 absorption of the liquefied gas fuel;
.4 shrinkage;
.5 ageing;
.6 closed cell content;
.7 density;

[10] Refer to section 6.4.16.

.8 mechanical properties, to the extent that they are subjected to liquefied gas fuel and other loading effects, thermal expansion and contraction;

.9 abrasion;

.10 cohesion;

.11 thermal conductivity;

.12 resistance to vibrations;

.13 resistance to fire and flame spread; and

.14 resistance to fatigue failure and crack propagation.

6.4.13.3.3 The above properties, where applicable, shall be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than minus 196°C.

6.4.13.3.4 Due to location or environmental conditions, thermal insulation materials shall have suitable properties of resistance to fire and flame spread and shall be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, and in way of tank cover penetrations, it shall have suitable fire resistance properties in accordance with a recognized standard or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal.

6.4.13.3.5 Thermal insulation that does not meet recognized standards for fire resistance may be used in fuel storage hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame spread characteristics and that forms an efficient approved vapour seal.

6.4.13.3.6 Testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples.

LR 6.4-31 Proposals for the thermal conductivity tests of aged samples of the insulation are to be submitted by the designer and/or insulation makers, and are to be agreed with LR based on the physical and chemical characteristics of the insulation.

6.4.13.3.7 Where powder or granulated thermal insulation is used, measures shall be taken to reduce compaction in service and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the liquefied gas fuel containment system.

LR 6.4-32 Particular attention is to be paid to the cleaning of the steelwork prior to the application of the insulation. Where insulation is to be foamed or sprayed *in situ*, the minimum steelwork temperature at the time of application is to be indicated in the specification in addition to environmental conditions.

6.4.14 Construction processes

LR 6.4-33 In addition to an inspection/survey plan as specified in 6.4.1.8 for the through life maintenance of the fuel containment system, a construction, testing and inspection (CTI) plan for the installation of the containment system is to be submitted for approval. This plan is to list the following sequentially for each stage of installation, testing and inspection:

(a) The method to be used;

(b) The acceptance criteria;

(c) The form of record to be made;

(d) The involvement of the shipyard, containment system designer where relevant, and LR Surveyor.

Further detailed documents, which may be cross-referenced by the CTI plan, are to be submitted for approval as applicable.

6.4.14.1 Weld joint design

LR 6.4-34 The requirements of this Section are to be applied in association with the relevant Chapters of the Rules for Ships. For welding joint details of pressure vessels, *see Pt 5, Ch 10,14* of the Rules for Ships.

6.4.14.1.1 All welded joints of the shells of independent tanks shall be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure. Except for small penetrations on domes, nozzle welds are also to be designed with full penetration.

LR 6.4-35 In the context of 6.4.14.1.1, small penetrations may generally be considered as penetrations of diameter not greater than 50 mm. Penetrations of diameter not greater than 150 mm may also be considered as being small, provided the service temperature is not lower than -110ºC, and the tank design pressure is not greater than 0,07MPa.

LR 6.4-36 In accordance with 6.4.14.1.1 full penetration T-butt welds may be used for dome-to-shell connections. Full penetration T-butt welds between shell and longitudinal bulkhead for bi-lobe tanks may also be accepted subject to agreement from the National Administration, *see also* 6.4.14.1.2.1.

6.4.14.1.2 Welding joint details for type C independent tanks, and for the liquid-tight primary barriers of type B independent tanks primarily constructed of curved surfaces, shall be as follows:

.1 All longitudinal and circumferential joints shall be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds shall be obtained by double welding or by the use of backing rings. If used, backing rings shall be removed except from very small process pressure vessels.[11] Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure. For connections of tank shell to a longitudinal bulkhead of type C bilobe tanks, tee welds of the full penetration type may be accepted.

.2 The bevel preparation of the joints between the tank body and domes and between domes and relevant fittings shall be designed according to a standard acceptable to the Administration. All welds connecting nozzles, domes or other penetrations of the vessel and all welds connecting flanges to the vessel or nozzles shall be full penetration welds.

6.4.14.2 Design for gluing and other joining processes

6.4.14.2.1 The design of the joint to be glued (or joined by some other process except welding) shall take account of the strength characteristics of the joining process.

6.4.15 Tank types

6.4.15.1 Type A independent tanks

6.4.15.1.1 Design basis

6.4.15.1.1.1 Type A independent tanks are tanks primarily designed using classical ship-structural analysis procedures in accordance with the requirements of the Administration. Where such tanks are primarily constructed of plane surfaces, the design vapour pressure P_0 shall be less than 0.07 MPa.

6.4.15.1.1.2 A complete secondary barrier is required as defined in 6.4.3. The secondary barrier shall be designed in accordance with 6.4.4.

6.4.15.1.2 Structural analysis

6.4.15.1.2.1 A structural analysis shall be performed taking into account the internal pressure as indicated in 6.4.9.3.3.1, and the interaction loads with the supporting and keying system as well as a reasonable part of the ship's hull.

6.4.15.1.2.2 For parts, such as structure in way of supports, not otherwise covered by the regulations in this Code, stresses shall be determined by direct calculations, taking into account the loads referred to in 6.4.9.2 to 6.4.9.5 as far as applicable, and the ship deflection in way of supports.

LR 6.4-37 Symbols:

b = width of plating supported, in metres

f = $1,1 - \frac{s}{2500S}$ but need not exceed 1,0

f_s = 2,7 for nickel steels and carbon manganese steels

= 3,9 for austenitic steels and aluminium alloys

h = load head, in metres measured as follows:

(a) for plating, the distance vertically from a point one-third of the height of the plate above its lower edge to the top of the tank

(b) for stiffeners, the distance from the middle of the effective length to the top of the tank.

l = effective span or girder or web, in metres, *see* Pt 3, Ch 3,3.3

[11] For vacuum insulated tanks without manhole, the longitudinal and circumferential joints should meet the aforementioned requirements, except for the erection weld joint of the outer shell, which may be a one-side welding with backing rings.

l_e = effective length of stiffening member, in metres, *see* Pt 3, Ch 3,3.3

l_t, l_s, l_b, l_c are effective spans measured according to Fig. LR 6.1

ρ = maximum density of the fuel, in kg/m^3, at the design temperature

k = higher tensile steel factor, *see* Pt 3, Ch 2,1.2 of the Rules for Ships

t_p = thickness, in mm, of the attached load bearing plating. Where this varies over the effective width of plating, the mean thickness is to be used.

P = harbour relief valve pressure, in MPa

P_{eq} = the internal pressure head, in MPa, as derived from 6.4.9.3.3.1.4 and measured at a point on the plate one-third of the depth of the plate above its lower edge

s = spacing of bulkhead stiffeners, in mm

S = spacing of primary members, in metres

S_w and $s1$ are as defined in *Pt 3, Ch 10, Table 10.5.1* of the Rules for Ships

The lateral and torsional stability of stiffeners is to comply with the requirements of Pt 4, Ch 9,5.6 of the Rules for Ships.

LR 6.4-38 The scantlings of the fuel tanks are to comply with the requirements of LR 6.4-39 and the following:

(a) Minimum thickness.

No part of the fuel tank structure is to be less than 7,5 mm in thickness.

(b) Boundary plating.

The thickness of plating forming the boundaries of fuel tanks is to be not less than 7,5 mm, nor less than:

$$t = 0,035 s f \sqrt{P_{eq} k} \text{ mm}$$

NOTE
Additional corrosion allowance of 1 mm is to be added to the thickness derived if the fuel is of corrosive nature, *see also* 6.4.1.7.
where

(c) Rolled or built stiffeners.

The section modulus of rolled or built stiffeners on plating forming tank boundaries is to be not less than:

$$Z = \frac{10 P_{eq} s k l_e^2}{f_s \gamma (\omega_1 + \omega_2 + 2)} \text{ cm}^3$$

(d) Transverses.

The scantlings of transverse members are normally to be derived using direct calculation methods. The structural analysis is to take account of the internal pressure defined in 6.4.9.3.3.1.4 and also those resulting from structural test loading conditions. Proper account is also to be taken of structural model end constraints, shear and axial forces present and any interaction from the double bottom structure through the fuel tank supports. As an initial estimate the scantlings of the primary transverses may be taken as:

Top transverse

$$Z = 720 P_{eq} s l_t^2 k \text{ cm}^3$$

Topside transverse

$$Z = 520 P_{eq} s l_t^2 k \text{ cm}^3$$

Side transverse

$$Z = 560 P_{eq} s l_s^2 k \text{ cm}^3$$

Bottom transverse

$Z = 560 P_{eq} s l_b{}^2 k$ cm^3

Centreline bulkhead transverse

$Z = 400 P_{eq} s l_c{}^2 k$ cm^3

The depth of the bottom transverse web is generally to be not less than $\frac{l_b}{4}$.

Web stiffening is to be in accordance with Pt 4, Ch 9,10.5 of the Rules for Ships with the application of the stiffening requirements as shown in Fig. LR 6.1.

(e) Tank end webs and girders.

The section modulus of vertical webs and horizontal girders is to be not less than:

$$Z = 850 P_{eq} b l^2 k \text{ cm}^3$$

(f) Internal bulkheads (Perforated).

The thickness of plating is to be not less than 7,5 mm, but may require to be increased at the tank boundaries in regions of high local loading. The section modulus of stiffeners, girders and webs is to be in accordance with Pt 4, Ch 9,8 and Ch 9,9.8 of the Rules for Ships.

(g) Internal bulkheads (Non-perforated).

(i) Where a bulkhead may be subjected to an internal pressure head, P_{eq}, resulting from loading on one side only, the scantlings of plating and stiffeners are to be determined from (b) and (c), *see also* (j).

(ii) Where no such loading condition is envisaged, and where the arrangement of the centreline bulkhead in way of the tank dome creates a common vapour space between the port and starboard sides of the tank, the scantlings may be derived as follows:

The thickness of plating and the section modulus of stiffeners are to be derived from (b) and (c) respectively, but P_{eq} (in MPa) need not exceed the greater of:

$\frac{h\rho}{1,02x10^5}$, or

P_{HP} - P_{air}, or

$\frac{a_y b_t \rho}{1,02x10^5}$.

where

P_{HP} = tank testing load

P_{air} = air test pressure

b_t = maximum breadth from centreline bulkhead to tank side

a_y = maximum dimensionless accelerations in transverse direction

In such instances, due consideration is to be given to the tank testing procedures and the loading manual is to include the following note:

'Centreline bulkhead scantlings of fuel tanks are approved for symmetrical filling levels either side of the centreline bulkhead in sea-going conditions.'

(h) Tank crown structure.

Where the minimum thickness of tank boundary plating (7,5 mm) has been adopted, the section modulus of associated stiffeners and transverses are to be derived as above, but P_{eq} is to be not less than:

$$P_{\text{eq min}} = \left(\frac{7,5}{0,035 s f \sqrt{k}}\right)^2 \text{ MPa}$$

The tank crown plating and stiffeners are also to be suitable for a head equivalent to the greater of:

the harbour relief valve pressure; or

the tank test air pressure where the tank is to be hydropneumatically tested.

(i) Connection of stiffeners to primary supporting members.

In assessing the arrangement at intersections of continuous secondary and primary members, the requirements of Pt 3, Ch 10,5.2 are to be complied with using the requirements for other ship types. The total load, P, in kN, is to be derived using the internal pressure head, P_{eq}, in MPa as given in 6.4.9.3.3.1.4 and the following formulae:

(i) In general:

$P = 1000\ (S_w - 0{,}5s_1)\ s_1\ P_{eq}$ kN

(ii) For wash bulkheads:

$P = 1200\ (S_w - 0{,}5s_1)\ s_1\ P_{eq}$ kN

(j) Where the fuel tank boundary scantlings are based on the internal pressure head, Z_β, measured with respect to the non-perforated internal bulkhead such as centreline bulkhead, the valve(s) fitted in the bulkhead are to normally be kept closed and only be used for levelling operations. This is to be indicated in the operational manual required in 18.2.

6.4.15.1.2.3 The tanks with supports shall be designed for the accidental loads specified in 6.4.9.5. These loads need not be combined with each other or with environmental loads.

LR 6.4-39 In accordance with 6.4.15.1.2.3 tank boundaries and transverse wash bulkheads, where fitted, shall be able to withstand a collision force acting on the tank supports in the forward and aft directions without deformation likely to endanger the tank structure, *see* 6.4.9.5.1

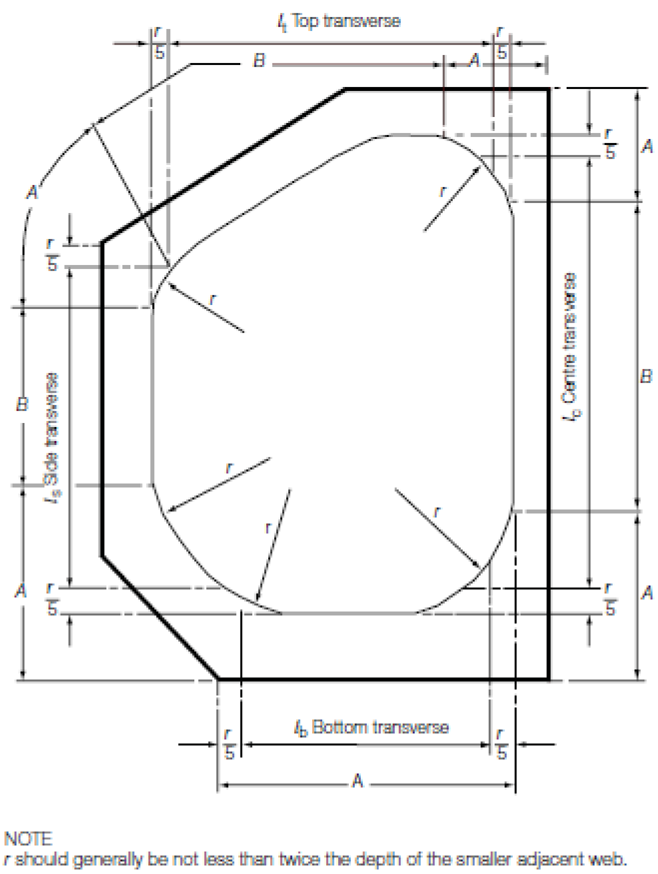

Fig. LR 6.1 Measurement of spans

6.4.15.1.3 Ultimate design condition

6.4.15.1.3.1 For tanks primarily constructed of plane surfaces, the nominal membrane stresses for primary and secondary members (stiffeners, web frames, stringers, girders), when calculated by classical analysis procedures, shall not exceed the lower of $R_m/2.66$ or $R_e/1.33$ for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys, where R_m and R_e are defined in 6.4.12.1.1.3. However, if detailed calculations are carried out for the primary members, the equivalent stress σc, as defined in 6.4.12.1.1.4, may be increased over that indicated above to a stress acceptable to the Administration. Calculations shall take into account the effects of bending, shear, axial and torsional deformation as well as the hull/liquefied gas fuel tank interaction forces due to the deflection of the hull structure and liquefied gas fuel tank bottoms.

6.4.15.1.3.2 Tank boundary scantlings shall meet at least the requirements of the Administration for deep tanks taking into account the internal pressure as indicated in 6.4.9.3.3.1 and any corrosion allowance required by 6.4.1.7.

6.4.15.1.3.3 The liquefied gas fuel tank structure shall be reviewed against potential buckling.

6.4.15.1.4 Accidental design condition

6.4.15.1.4.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 6.4.9.5 and 6.4.1.6.3 as relevant.

6.4.15.1.4.2 When subjected to the accidental loads specified in 6.4.9.5, the stress shall comply with the acceptance criteria specified in 6.4.15.1.3, modified as appropriate taking into account their lower probability of occurrence.

6.4.15.2 Type B independent tanks

6.4.15.2.1 Design basis

6.4.15.2.1.1 Type B independent tanks are tanks designed using model tests, refined analytical tools and analysis methods to determine stress levels, fatigue life and crack propagation characteristics. Where such tanks are primarily constructed of plane surfaces (prismatic tanks) the design vapour pressure P_0 shall be less than 0.07 MPa.

6.4.15.2.1.2 A partial secondary barrier with a protection system is required as defined in 6.4.3. The small leak protection system shall be designed according to 6.4.5.

6.4.15.2.2 Structural analysis

6.4.15.2.2.1 The effects of all dynamic and static loads shall be used to determine the suitability of the structure with respect to:

.1 plastic deformation;

.2 buckling;

.3 fatigue failure; and

.4 crack propagation.

Finite element analysis or similar methods and fracture mechanics analysis or an equivalent approach, shall be carried out.

6.4.15.2.2.2 A three-dimensional analysis shall be carried out to evaluate the stress levels, including interaction with the ship's hull. The model for this analysis shall include the liquefied gas fuel tank with its supporting and keying system, as well as a reasonable part of the hull.

6.4.15.2.2.3 A complete analysis of the particular ship accelerations and motions in irregular waves, and of the response of the ship and its liquefied gas fuel tanks to these forces and motions, shall be performed unless the data is available from similar ships.

6.4.15.2.3 Ultimate design condition

6.4.15.2.3.1 Plastic deformation

For type B independent tanks, primarily constructed of bodies of revolution, the allowable stresses shall not exceed:

$\sigma_m \leq f$

$\sigma_L \leq 1.5f$

$\sigma_b \leq 1.5F$

$\sigma_L + \sigma_b \leq 1.5F$

$\sigma_m + \sigma_b \leq 1.5F$

$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$

$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$

where:

σ_m = equivalent primary general membrane stress;

σ_L = equivalent primary local membrane stress;
σ_b = equivalent primary bending stress;
σ_g = equivalent secondary stress;
f = the lesser of (*Rm* / A) or (*Re* / B); and
F = the lesser of (*Rm* / C) or (*Re* / D),

with $R_m$and R_e as defined in 6.4.12.1.1.3. With regard to the stresses σ_m, σ_L , σ_g and σ_b see also the definition of stress categories in 6.4.15.2.3.6.

The values A and B shall have at least the following minimum values:

	Nickel steels and carbon manganese steels	**Austenitic steel**	**Aluminium alloys**
A	3	3.5	4
B	2	1.6	1.5
C	3	3	3
D	1.5	1.5	1.5

The above figures may be altered considering the design condition considered in acceptance with the Administration. For type B independent tanks, primarily constructed of plane surfaces, the allowable membrane equivalent stresses applied for finite element analysis shall not exceed:

.1 for nickel steels and carbon-manganese steels, the lesser of R_m /2 or R_e /1.2;
.2 for austenitic steels, the lesser of R_m /2.5 or R_e /1.2; and
.3 for aluminium alloys, the lesser of R_m /2.5 or R_e /1.2.

The above figures may be amended considering the locality of the stress, stress analysis methods and design condition considered in acceptance with the Administration.

The thickness of the skin plate and the size of the stiffener shall not be less than those required for type A independent tanks.

LR 6.4-40 Type B independent tanks constructed of bodies of revolution are to be designed to comply with the allowable stresses given in 6.4.15.2.3.1.

LR 6.4-41 The stress levels to be complied with for Type B independent tanks primarily constructed of plane surfaces will be specially considered.

LR 6.4-42 Type B independent tanks are to be subjected to a structural analysis by direct calculation procedures at a high confidence level. It is recommended that the assumptions made and the proposed calculation procedures be agreed with LR at an early stage. Where necessary, model or other tests may be required. Generally the scantlings of fuel tanks primarily constructed of plane surfaces are not to be less than required by LR 6.4-37 and LR 6.4-39 for Type A independent tanks.

6.4.15.2.3.2 Buckling

Buckling strength analyses of liquefied gas fuel tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognized standards. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, lack of straightness or flatness, ovality and deviation from true circular form over a specified arc or chord length, as applicable.

6.4.15.2.3.3 Fatigue design condition

6.4.15.2.3.3.1 Fatigue and crack propagation assessment shall be performed in accordance with the provisions of 6.4.12.2. The acceptance criteria shall comply with 6.4.12.2.7, 6.4.12.2.8 or 6.4.12.2.9, depending on the detectability of the defect.

6.4.15.2.3.3.2 Fatigue analysis shall consider construction tolerances.

6.4.15.2.3.3.3 Where deemed necessary by the Administration, model tests may be required to determine stress concentration factors and fatigue life of structural elements.

LR 6.4-43 Fatigue and crack propagation assessment shall be performed in accordance with 6.4.12.2. The acceptance criteria shall comply with 6.4.12.2.7, 6.4.12.2.8 or 6.4.12.2.9, depending on the detectability of the defect. Due consideration of quality control aspects such as misalignment, distortion, fit-up and weld shape are also to be taken into account. In general, and in

addition to the C_w values dependent on detectability specified in 6.4.12.2.7, 6.4.12.2.8 and 6.4.12.2.9, a C_w value of 0,1 is to be used for all primary members. Alternative proposals will be specially considered.

6.4.15.2.3.4 Accidental design condition

6.4.15.2.3.4.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 6.4.9.5 and 6.4.1.6.3, as relevant.

6.4.15.2.3.4.2 When subjected to the accidental loads specified in 6.4.9.5, the stress shall comply with the acceptance criteria specified in 6.4.15.2.3, modified as appropriate, taking into account their lower probability of occurrence.

6.4.15.2.3.5 Marking

Any marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

6.4.15.2.3.6 Stress categories

For the purpose of stress evaluation, stress categories are defined in this section as follows:

.1 *Normal stress* is the component of stress normal to the plane of reference.

.2 *Membrane stress* is the component of normal stress that is uniformly distributed and equal to the average value of the stress across the thickness of the section under consideration.

.3 *Bending stress* is the variable stress across the thickness of the section under consideration, after the subtraction of the membrane stress.

.4 *Shear stress* is the component of the stress acting in the plane of reference.

.5 *Primary stress* is a stress produced by the imposed loading, which is necessary to balance the external forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or at least in gross deformations.

.6 *Primary general membrane stress* is a primary membrane stress that is so distributed in the structure that no redistribution of load occurs as a result of yielding.

.7 *Primary local membrane stress* arises where a membrane stress produced by pressure or other mechanical loading and associated with a primary or a discontinuity effect produces excessive distortion in the transfer of loads for other portions of the structure. Such a stress is classified as a primary local membrane stress, although it has some characteristics of a secondary stress. A stress region may be considered as local, if:

$S_1 \leq 0.5\sqrt{Rt}$; and

$S_1 \geq 2.5\sqrt{Rt}$

where:

S_1 = distance in the meridional direction over which the equivalent stress exceeds 1.1f;

S_2 = distance in the meridional direction to another region where the limits for primary general membrane stress are exceeded;

R = mean radius of the vessel;

t = wall thickness of the vessel at the location where the primary general membrane stress limit is exceeded; and

f = allowable primary general membrane stress.

.8 *Secondary stress* is a normal stress or shear stress developed by constraints of adjacent parts or by self-constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur.

6.4.15.3 Type C independent tanks

6.4.15.3.1 Design basis

6.4.15.3.1.1 The design basis for type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria. The minimum design pressure defined in 6.4.15.3.1.2 is intended to ensure that the dynamic stress is sufficiently low so that an initial surface flaw will not propagate more than half the thickness of the shell during the lifetime of the tank.

6.4.15.3.1.2 The design vapour pressure shall not be less than:

$$P_0 = 0.2 + AC(\rho_r)^{1.5} \text{ (MPa)}$$

where:

$$A = 0.00185\left(\frac{\sigma_m}{\Delta\sigma_A}\right)^2$$

with:

σ_m = design primary membrane stress;

$\Delta\sigma_A$= allowable dynamic membrane stress (double amplitude at probability level Q = 10^{-8}) and equal to:

- 55 N/mm^2 for ferritic-perlitic, martensitic and austenitic steel;
- 25 N/mm^2 for aluminium alloy (5083-O);

C = a characteristic tank dimension to be taken as the greatest of the following:

h, 0.75*b* or 0.*45ℓ,*

with:

h = height of tank (dimension in ship's vertical direction) (m);

b = width of tank (dimension in ship's transverse direction) (m);

ℓ = length of tank (dimension in ship's longitudinal direction) (m);

ρ_r = the relative density of the cargo (ρ_r = 1 for fresh water) at the design temperature.

LR 6.4-44 Alternative means of calculating the design vapour pressure referred to in 6.4.15.3.1.2 may be specially considered and are to be acceptable to the National Administration.

LR 6.4-45 Before construction of the pressure vessels is commenced, the following particulars, where applicable, and plans are to be submitted for approval:

(a) Nature of fuel, together with maximum vapour pressures and minimum liquid temperature for which the pressure vessels are to be approved, and proposed hydraulic test pressure.

(b) Particulars of materials proposed for the construction of the vessels.

(c) Particulars of refrigeration equipment.

(d) General arrangement plan showing location of pressure vessels in the ship.

(e) Plans of pressure vessels showing attachments, openings, dimensions, details of welded joints and particulars of proposed stress relief heat treatment.

(f) Plans of seatings, securing arrangements and deck sealing arrangements.

(g) Plans showing arrangement of mountings, level gauges and number, type and size of safety valves.

(h) In the case of vacuum insulated tanks, plans detailing the supports/mountings for anchoring and supporting the inner tank taking account of static and dynamic loads, thermal changes to inner tank and materials used.

6.4.15.3.2 Shell thickness

6.4.15.3.2.1 In considering the shell thickness the following apply:

.1 for pressure vessels, the thickness calculated according to 6.4.15.3.2.4 shall be considered as a minimum thickness after forming, without any negative tolerance;

.2 for pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, shall not be less than 5 mm for carbon manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminium alloys; and

.3 the welded joint efficiency factor to be used in the calculation according to 6.4.15.3.2.4 shall be 0.95 when the inspection and the non-destructive testing referred to in 16.3.6.4 are carried out. This figure may be increased up to 1.0 when account is taken of other considerations, such as the material used, type of joints, welding procedure and type of loading. For process pressure vessels the Administration may accept partial non-destructive examinations, but not less than those of 16.3.6.4, depending on such factors as the material used, the design temperature, the nil ductility transition temperature of the material as fabricated and the type of joint and welding procedure, but in this case an efficiency factor of not more than 0.85 shall be adopted. For special materials the above-mentioned factors shall be reduced, depending on the specified mechanical properties of the welded joint.

6.4.15.3.2.2 The design liquid pressure defined in 6.4.9.3.3.1 shall be taken into account in the internal pressure calculations.

6.4.15.3.2.3 The design external pressure P_e, used for verifying the buckling of the pressure vessels, shall not be less than that given by:

$P_e = P_1 + P_2 + P_3 + P_4$ (MPa)

where:

P_1 = setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves P_1shall be specially considered, but shall not in general be taken as less than 0.025 MPa.

P_2 = the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere P_2= 0.

P_3 = compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both shall be taken into account.

P_4 = external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere P_4= 0.

6.4.15.3.2.4 Scantlings based on internal pressure shall be calculated as follows:

The thickness and form of pressure-containing parts of pressure vessels, under internal pressure, as defined in 6.4.9.3.3.1, including flanges, shall be determined. These calculations shall in all cases be based on accepted pressure vessel design theory. Openings in pressure-containing parts of pressure vessels shall be reinforced in accordance with a recognized standard acceptable to the Administration.

LR 6.4-46 The thickness of pressure parts subject to internal pressure is to be in accordance with Pt 5, Ch 11 of the Rules for Ships except that:

(a) the welded joint efficiency factor, J, is to be as defined in 6.4.15.3.2.1.3;

(b) the allowable stress is to be in accordance with 6.4.15.3.3.1;

(c) the constant thickness increment (0,75 mm) included in the formulae in Pt 5, Ch 11,2 of the Rules for Ships may require to be increased in accordance with 6.4.1.7.

6.4.15.3.2.5 Stress analysis in respect of static and dynamic loads shall be performed as follows:

.1 pressure vessel scantlings shall be determined in accordance with 6.4.15.3.2.1 to 6.4.15.3.2.4 and 6.4.15.3.3;

.2 calculations of the loads and stresses in way of the supports and the shell attachment of the support shall be made. Loads referred to in 6.4.9.2 to 6.4.9.5 shall be used, as applicable. Stresses in way of the supports shall be to a recognized standard acceptable to the Administration. In special cases a fatigue analysis may be required by the Administration; and

.3 if required by the Administration, secondary stresses and thermal stresses shall be specially considered.

LR 6.4-47 Where the inner hull directly supports the containment system, it is to comply with the requirements of LR 3.18-02 of the Rules for Ships for Liquefied Gases.

6.4.15.3.3 Ultimate design condition

6.4.15.3.3.1 Plastic deformation

For type C independent tanks, the allowable stresses shall not exceed:

$\sigma_m \leq f$
$\sigma_L \leq 1.5f$
$\sigma_b \leq 1.5f$
$\sigma_L + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b \leq 1.5f$
$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$
$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$

where:

σ_m = equivalent primary general membrane stress;
σ_L = equivalent primary local membrane stress;

σ_b = equivalent primary bending stress;

σ_g = equivalent secondary stress; and

f = the lesser of R_m/A or R_e/B,

with R_m and $R_e$as defined in 6.4.12.1.1.3. With regard to the stresses σ_m , σ_L, σ_g and σ_b see also the definition of stress categories in 6.4.15.2.3.6. The values A and B shall have at least the following minimum values:

	Nickel steels and carbon-manganese steels	Austenitic steels	Aluminium alloys
A	3	3.5	4
B	1.5	1.5	1.5

6.4.15.3.3.2 Buckling criteria shall be as follows:

The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses shall be based on calculations using accepted pressure vessel buckling theory and shall adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

6.4.15.3.4 Fatigue design condition

6.4.15.3.4.1 For type C independent tanks where the liquefied gas fuel at atmospheric pressure is below minus 55°C, the Administration may require additional verification to check their compliance with 6.4.15.3.1.1, regarding static and dynamic stress depending on the tank size, the configuration of the tank and arrangement of its supports and attachments.

6.4.15.3.4.2 For vacuum insulated tanks, special attention shall be made to the fatigue strength of the support design and special considerations shall also be made to the limited inspection possibilities between the inside and outer shell.

6.4.15.3.5 Accidental design condition

6.4.15.3.5.1 The tanks and the tank supports shall be designed for the accidental loads and design conditions specified in 6.4.9.5 and 6.4.1.6.3, as relevant.

6.4.15.3.5.2 When subjected to the accidental loads specified in 6.4.9.5, the stress shall comply with the acceptance criteria specified in 6.4.15.3.3.1, modified as appropriate taking into account their lower probability of occurrence.

6.4.15.3.6 Marking

The required marking of the pressure vessel shall be achieved by a method that does not cause unacceptable local stress raisers.

6.4.15.4 Membrane tanks

6.4.15.4.1 Design basis

6.4.15.4.1.1 The design basis for membrane containment systems is that thermal and other expansion or contraction is compensated for without undue risk of losing the tightness of the membrane.

6.4.15.4.1.2 A systematic approach, based on analysis and testing, shall be used to demonstrate that the system will provide its intended function in consideration of the identified in service events as specified in 6.4.15.4.2.1.

6.4.15.4.1.3 A complete secondary barrier is required as defined in 6.4.3. The secondary barrier shall be designed according to 6.4.4.

6.4.15.4.1.4 The design vapour pressure P_0 shall not normally exceed 0.025 MPa. If the hull scantlings are increased accordingly and consideration is given, where appropriate, to the strength of the supporting thermal insulation, P_0 may be increased to a higher value but less than 0.070 MPa.

6.4.15.4.1.5 The definition of membrane tanks does not exclude designs such as those in which non-metallic membranes are used or where membranes are included or incorporated into the thermal insulation.

6.4.15.4.1.6 The thickness of the membranes shall normally not exceed 10 mm.

6.4.15.4.1.7 The circulation of inert gas throughout the primary and the secondary insulation spaces, in accordance with 6.11.1 shall be sufficient to allow for effective means of gas detection.

6.4.15.4.2 Design considerations

6.4.15.4.2.1 Potential incidents that could lead to loss of fluid tightness over the life of the membranes shall be evaluated. These include, but are not limited to:

.1 Ultimate design events:

.1 tensile failure of membranes;
.2 compressive collapse of thermal insulation;
.3 thermal ageing;
.4 loss of attachment between thermal insulation and hull structure;
.5 loss of attachment of membranes to thermal insulation system;
.6 structural integrity of internal structures and their associated supporting structures; and
.7 failure of the supporting hull structure.

.2 Fatigue design events:

.1 fatigue of membranes including joints and attachments to hull structure;
.2 fatigue cracking of thermal insulation;
.3 fatigue of internal structures and their associated supporting structures; and
.4 fatigue cracking of inner hull leading to ballast water ingress.

.3 Accident design events:

.1 accidental mechanical damage (such as dropped objects inside the tank while in service);
.2 accidental over pressurization of thermal insulation spaces;
.3 accidental vacuum in the tank; and
.4 water ingress through the inner hull structure.

Designs where a single internal event could cause simultaneous or cascading failure of both membranes are unacceptable.

6.4.15.4.2.2 The necessary physical properties (mechanical, thermal, chemical, etc.) of the materials used in the construction of the liquefied gas fuel containment system shall be established during the design development in accordance with 6.4.15.4.1.2.

6.4.15.4.3 Loads, load combinations

Particular consideration shall be paid to the possible loss of tank integrity due to either an overpressure in the interbarrier space, a possible vacuum in the liquefied gas fuel tank, the sloshing effects, to hull vibration effects, or any combination of these events.

6.4.15.4.4 Structural analyses

6.4.15.4.4.1 Structural analyses and/or testing for the purpose of determining the ultimate strength and fatigue assessments of the liquefied gas fuel containment and associated structures and equipment noted in 6.4.7 shall be performed. The structural analysis shall provide the data required to assess each failure mode that has been identified as critical for the liquefied gas fuel containment system.

6.4.15.4.4.2 Structural analyses of the hull shall take into account the internal pressure as indicated in 6.4.9.3.3.1. Special attention shall be paid to deflections of the hull and their compatibility with the membrane and associated thermal insulation.

6.4.15.4.4.3 The analyses referred to in 6.4.15.4.4.1 and 6.4.15.4.4.2 shall be based on the particular motions, accelerations and response of ships and liquefied gas fuel containment systems.

LR 6.4-48 The hull structure supporting the membrane tank is to be incorporated into the ship structure finite element model. The scantlings of the inner hull are to be not less than required by LR 3.21-04 of the Rules for Ships for Liquefied Gases, *see also* LR 3.22-01 of the Rules for Ships for Liquefied Gases.

6.4.15.4.5 Ultimate design condition

6.4.15.4.5.1 The structural resistance of every critical component, sub-system, or assembly, shall be established, in accordance with 6.4.15.4.1.2, for in-service conditions.

6.4.15.4.5.2 The choice of strength acceptance criteria for the failure modes of the liquefied gas fuel containment system, its attachments to the hull structure and internal tank structures, shall reflect the consequences associated with the considered mode of failure.

6.4.15.4.5.3 The inner hull scantlings shall meet the regulations for deep tanks, taking into account the internal pressure as indicated in 6.4.9.3.3.1 and the specified appropriate regulations for sloshing load as defined in 6.4.9.4.1.3.

6.4.15.4.6 Fatigue design condition

6.4.15.4.6.1 Fatigue analysis shall be carried out for structures inside the tank, i.e. pump towers, and for parts of membrane and pump tower attachments, where failure development cannot be reliably detected by continuous monitoring.

6.4.15.4.6.2 The fatigue calculations shall be carried out in accordance with 6.4.12.2, with relevant regulations depending on:

.1 the significance of the structural components with respect to structural integrity; and

.2 availability for inspection.

6.4.15.4.6.3 For structural elements for which it can be demonstrated by tests and/or analyses that a crack will not develop to cause simultaneous or cascading failure of both membranes, C_w shall be less than or equal to 0.5.

6.4.15.4.6.4 Structural elements subject to periodic inspection, and where an unattended fatigue crack can develop to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics regulations stated in 6.4.12.2.8.

6.4.15.4.6.5 Structural element not accessible for in-service inspection, and where a fatigue crack can develop without warning to cause simultaneous or cascading failure of both membranes, shall satisfy the fatigue and fracture mechanics regulations stated in 6.4.12.2.9.

LR 6.4-49 Containment system details to be investigated by fatigue analysis are to be submitted to LR for consideration, and it is recommended that this be done at as early a stage as possible.

6.4.15.4.7 Accidental design condition

6.4.15.4.7.1 The containment system and the supporting hull structure shall be designed for the accidental loads specified in 6.4.9.5. These loads need not be combined with each other or with environmental loads.

6.4.15.4.7.2 Additional relevant accidental scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside of tanks.

6.4.16 Limit state design for novel concepts

6.4.16.1 Fuel containment systems that are of a novel configuration that cannot be designed using section 6.4.15 shall be designed using this section and 6.4.1 to 6.4.14, as applicable. Fuel containment system design according to this section shall be based on the principles of limit state design which is an approach to structural design that can be applied to established design solutions as well as novel designs. This more generic approach maintains a level of safety similar to that achieved for known containment systems as designed using 6.4.15.

6.4.16.2 The limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 6.4.1.6. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the regulations.

6.4.16.3 For each failure mode, one or more limit states may be relevant. By consideration of all relevant limit states, the limit load for the structural element is found as the minimum limit load resulting from all the relevant limit states. The limit states are divided into the three following categories:

.1 Ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain or deformation; under intact (undamaged) conditions.

.2 Fatigue limit states (FLS), which correspond to degradation due to the effect of time varying (cyclic) loading.

.3 Accident limit states (ALS), which concern the ability of the structure to resist accidental situations.

6.4.16.4 The procedure and relevant design parameters of the limit state design shall comply with the Standards for the Use of limit state methodologies in the design of fuel containment systems of novel configuration (LSD Standard), as set out in the annex to part A-1.

6.5 Regulations for portable liquefied gas fuel tanks

6.5.1 The design of the tank shall comply with 6.4.15.3. The tank support (container frame or truck chassis) shall be designed for the intended purpose.

6.5.2 Portable fuel tanks shall be located in dedicated areas fitted with:

.1 mechanical protection of the tanks depending on location and cargo operations;

.2 if located on open deck: spill protection and water spray systems for cooling; and

.3 if located in an enclosed space: the space is to be considered as a tank connection space.

6.5.3 Portable fuel tanks shall be secured to the deck while connected to the ship systems. The arrangement for supporting and fixing the tanks shall be designed for the maximum expected static and dynamic inclinations, as well as the maximum expected values of acceleration, taking into account the ship characteristics and the position of the tanks.

6.5.4 Consideration shall be given to the strength and the effect of the portable fuel tanks on the ship's stability.

6.5.5 Connections to the ship's fuel piping systems shall be made by means of approved flexible hoses or other suitable means designed to provide sufficient flexibility.

6.5.6 Arrangements shall be provided to limit the quantity of fuel spilled in case of inadvertent disconnection or rupture of the non-permanent connections.

6.5.7 The pressure relief system of portable tanks shall be connected to a fixed venting system.

6.5.8 Control and monitoring systems for portable fuel tanks shall be integrated in the ship's control and monitoring system. Safety system for portable fuel tanks shall be integrated in the ship's safety system (e.g. shutdown systems for tank valves, leak/gas detection systems).

6.5.9 Safe access to tank connections for the purpose of inspection and maintenance shall be ensured.

6.5.10 After connection to the ship's fuel piping system,

.1 with the exception of the pressure relief system in 6.5.6 each portable tank shall be capable of being isolated at any time;

.2 isolation of one tank shall not impair the availability of the remaining portable tanks; and

.3 the tank shall not exceed its filling limits as given in 6.8.

6.6 Regulations for CNG fuel containment

6.6.1 The storage tanks to be used for CNG shall be certified and approved by the Administration.

6.6.2 Tanks for CNG shall be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in 6.7.2.7 and 6.7.2.8.

6.6.3 Adequate means shall be provided to depressurize the tank in case of a fire which can affect the tank.

6.6.4 Storage of CNG in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by the Administration provided the following is fulfilled in addition to 6.3.4 to 6.3.6:

.1 adequate means are provided to depressurize and inert the tank in case of a fire which can affect the tank;

.2 all surfaces within such enclosed spaces containing the CNG storage are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

.3 a fixed fire-extinguishing system is installed in the enclosed spaces containing the CNG storage. Special consideration should be given to the extinguishing of jet-fires.

6.7 Regulations for pressure relief system

6.7.1 General

6.7.1.1 All fuel storage tanks shall be provided with a pressure relief system appropriate to the design of the fuel containment system and the fuel being carried. Fuel storage hold spaces, interbarrier spaces, tank connection spaces and tank cofferdams, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system. Pressure control systems specified in 6.9 shall be independent of the pressure relief systems.

6.7.1.2 Fuel storage tanks which may be subject to external pressures above their design pressure shall be fitted with vacuum protection systems.

6.7.2 Pressure relief systems for liquefied gas fuel tanks

6.7.2.1 If fuel release into the vacuum space of a vacuum insulated tank cannot be excluded, the vacuum space shall be protected by a pressure relief device which shall be connected to a vent system if the tanks are located below deck. On open deck a direct release into the atmosphere may be accepted by the Administration for tanks not exceeding the size of a 40 ft container if the released gas cannot enter safe areas.

6.7.2.2 Liquefied gas fuel tanks shall be fitted with a minimum of 2 pressure relief valves (PRVs) allowing for disconnection of one PRV in case of malfunction or leakage.

6.7.2.3 Interbarrier spaces shall be provided with pressure relief devices.[12] For membrane systems, the designer shall demonstrate adequate sizing of interbarrier space PRVs.

6.7.2.4 The setting of the PRVs shall not be higher than the vapour pressure that has been used in the design of the tank. Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.

6.7.2.5 The following temperature regulations apply to PRVs fitted to pressure relief systems:

.1 PRVs on fuel tanks with a design temperature below 0°C shall be designed and arranged to prevent their becoming inoperative due to ice formation;

.2 the effects of ice formation due to ambient temperatures shall be considered in the construction and arrangement of PRVs;

.3 PRVs shall be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised; and

.4 sensing and exhaust lines on pilot operated relief valves shall be of suitably robust construction to prevent damage.

6.7.2.6 In the event of a failure of a fuel tank PRV a safe means of emergency isolation shall be available.

.1 procedures shall be provided and included in the operation manual (refer to chapter 18);

.2 the procedures shall allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks shall be included to this effect; and

.3 isolation of the PRV shall be carried out under the supervision of the master. This action shall be recorded in the ship's log, and at the PRV.

6.7.2.7 Each pressure relief valve installed on a liquefied gas fuel tank shall be connected to a venting system, which shall be:

.1 so constructed that the discharge will be unimpeded and normally be directed vertically upwards at the exit;

.2 arranged to minimize the possibility of water or snow entering the vent system; and

.3 arranged such that the height of vent exits shall normally not be less than B/3 or 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways. However, vent mast height could be limited to lower value according to special consideration by the Administration.

6.7.2.8 The outlet from the pressure relief valves shall normally be located at least 10 m from the nearest:

.1 air intake, air outlet or opening to accommodation, service and control spaces, or other non-hazardous area; and

.2 exhaust outlet from machinery installations.

6.7.2.9 All other fuel gas vent outlets shall also be arranged in accordance with 6.7.2.7 and 6.7.2.8. Means shall be provided to prevent liquid overflow from gas vent outlets, due to hydrostatic pressure from spaces to which they are connected.

6.7.2.10 In the vent piping system, means for draining liquid from places where it may accumulate shall be provided. The PRVs and piping shall be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

6.7.2.11 Suitable protection screens of not more than 13 mm square mesh shall be fitted on vent outlets to prevent the ingress of foreign objects without adversely affecting the flow.

6.7.2.12 All vent piping shall be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.

[12] Refer to IACS Unified Interpretation GC9 entitled *Guidance for sizing pressure relief systems for interbarrier spaces, 1988.*

6.7.2.13 PRVs shall be connected to the highest part of the fuel tank. PRVs shall be positioned on the fuel tank so that they will remain in the vapour phase at the filling limit (FL) as given in 6.8, under conditions of 15° list and 0.015L trim, where L is defined in 2.2.25.

LR 6.7-01 Pressure relief valves are also to remain operable with the ship flooded to a final athwartships inclination to a maximum angle of 30°.

6.7.3 Sizing of pressure relieving system

6.7.3.1 Sizing of pressure relief valves

6.7.3.1.1 PRVs shall have a combined relieving capacity for each liquefied gas fuel tank to discharge the greater of the following, with not more than a 20% rise in liquefied gas fuel tank pressure above the MARVS:

.1 the maximum capacity of the liquefied gas fuel tank inerting system if the maximum attainable working pressure of the liquefied gas fuel tank inerting system exceeds the MARVS of the liquefied gas fuel tanks; or

.2 vapours generated under fire exposure computed using the following formula:

$Q = FGA^{0.82}$ (m^3/s)

where:

Q = minimum required rate of discharge of air at standard conditions of 273.15 Kelvin (K) and 0.1013 MPa.

F = fire exposure factor for different liquefied gas fuel types:

F = 1.0 for tanks without insulation located on deck;

F = 0.5 for tanks above the deck when insulation is approved by the Administration. (Approval will be based on the use of a fireproofing material, the thermal conductance of insulation, and its stability under fire exposure);

F = 0.5 for uninsulated independent tanks installed in holds;

F = 0.2 for insulated independent tanks in holds (or uninsulated independent tanks in insulated holds);

F = 0.1 for insulated independent tanks in inerted holds (or uninsulated independent tanks in inerted, insulated holds); and

F = 0.1 for membrane tanks.

For independent tanks partly protruding through the weather decks, the fire exposure factor shall be determined on the basis of the surface areas above and below deck.

G = gas factor according to formula:

$$G = \frac{12.4}{LD}\sqrt{\frac{ZT}{M}}$$

where:

T = temperature in Kelvin at relieving conditions, i.e. 120% of the pressure at which the pressure relief valve is set;

L = latent heat of the material being vaporized at relieving conditions, in kJ/kg;

D = a constant based on relation of specific heats k and is calculated as follows:

$$D = \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}$$

where:

k = ratio of specific heats at relieving conditions, and the value of which is between 1.0 and 2.2. If k is not known, D = 0.606 shall be used;

Z = compressibility factor of the gas at relieving conditions; if not known, Z = 1.0 shall be used;

M = molecular mass of the product.

The gas factor of each liquefied gas fuel to be carried is to be determined and the highest value shall be used for PRV sizing.

A = external surface area of the tank (m^2), as for different tank types, as shown in figure 6.7.1.

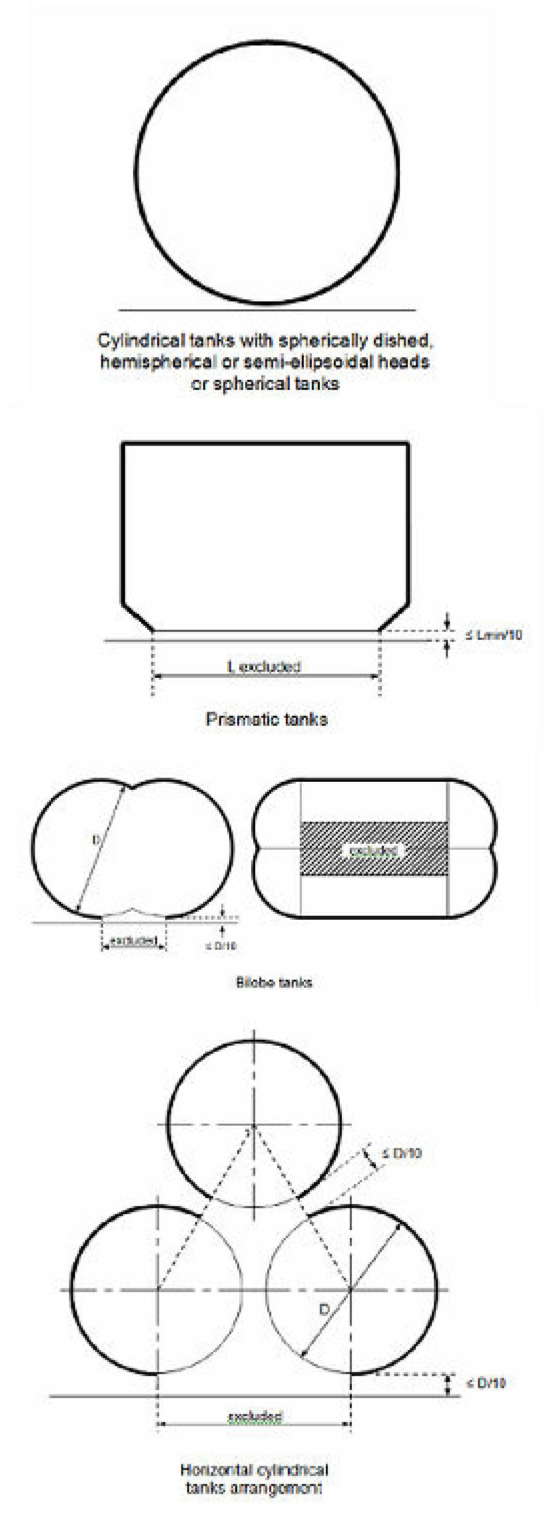

Figure 6.7.1

LR 6.7-01 Pressure relief valves are also to remain operable with the ship flooded to a final athwartships inclination to a maximum angle of 30°.

LR 6.7-02 For non-tapered prismatic tanks, L_{min}, is the smaller of the horizontal dimensions of the flat bottom of the tank. For tapered prismatic tanks, as would be used for the forward tank, L_{min} is the smaller of the length and the average width.

LR 6.7-03 For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is equal to or less than $L_{min}/10$:

A = external surface area minus flat bottom surface area.

LR 6.7-04 For prismatic tanks whose distance between the flat bottom of the tank and bottom of the hold space is greater than $L_{min}/10$:

A = external surface area.

6.7.3.1.2 For vacuum insulated tanks in fuel storage hold spaces and for tanks in fuel storage hold spaces separated from potential fire loads by coffer dams or surrounded by ship spaces with no fire load the following applies:

If the pressure relief valves have to be sized for fire loads the fire factors according may be reduced to the following values:

F = 0.5 to F = 0.25
F = 0.2 to F = 0.1
The minimum fire factor is F = 0.1

6.7.3.1.3 The required mass flow of air at relieving conditions is given by:

$$M_{air} = Q^{*} \rho_{air} \text{ (kg/s)}$$

where density of air (ρ_{air}) = 1.293 kg/m^3 (air at 273.15 K, 0.1013 MPa).

6.7.3.2 Sizing of vent pipe system

6.7.3.2.1 Pressure losses upstream and downstream of the PRVs, shall be taken into account when determining their size to ensure the flow capacity required by 6.7.3.1.

6.7.3.2.2 Upstream pressure losses

.1 the pressure drop in the vent line from the tank to the PRV inlet shall not exceed 3% of the valve set pressure at the calculated flow rate, in accordance with 6.7.3.1;
.2 pilot-operated PRVs shall be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome; and
.3 pressure losses in remotely sensed pilot lines shall be considered for flowing type pilots.

6.7.3.2.3 Downstream pressure losses

.1 Where common vent headers and vent masts are fitted, calculations shall include flow from all attached PRVs.
.2 The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections that join other tanks, shall not exceed the following values:

.1 for unbalanced PRVs: 10% of MARVS;
.2 for balanced PRVs: 30% of MARVS; and
.3 for pilot operated PRVs: 50% of MARVS.
Alternative values provided by the PRV manufacturer may be accepted.

6.7.3.2.4 To ensure stable PRV operation, the blow-down shall not be less than the sum of the inlet pressure loss and 0.02 MARVS at the rated capacity.

LR 6.7-05 The vent piping downstream of relief valves is to be designed and constructed taking into account potential two phase flow. Pressure drop calculations are to be undertaken in accordance with IMO Res. A829(19).

6.8 Regulations on loading limit for liquefied gas fuel tanks

6.8.1 Storage tanks for liquefied gas shall not be filled to more than a volume equivalent to 98% full at the reference temperature as defined in 2.2.36.

A loading limit curve for actual fuel loading temperatures shall be prepared from the following formula:

$$LL = FL\ \rho_R/\rho_L$$

where:

LL = loading limit as defined in 2.2.27, expressed in per cent;

FL = filling limit as defined in 2.2.16 expressed in per cent, here 98%;

ρ_R = relative density of fuel at the reference temperature; and

ρ_L = relative density of fuel at the loading temperature.

6.8.2 In cases where the tank insulation and tank location make the probability very small for the tank contents to be heated up due to an external fire, special considerations may be made to allow a higher loading limit than calculated using the reference temperature, but never above 95%. This also applies in cases where a second system for pressure maintenance is installed, (refer to 6.9). However, if the pressure can only be maintained / controlled by fuel consumers, the loading limit as calculated in 6.8.1 shall be used.

LR 6.8-01 The alternative loading limit option given under 6.8.2 is an alternative to 6.8.1 and shall only be applicable when the calculated loading limit using the formulae in 6.8.1 gives a lower value than 95 per cent.

6.9 Regulations for the maintaining of fuel storage condition

6.9.1 Control of tank pressure and temperature

6.9.1.1 With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature shall be maintained at all times within their design range by means acceptable to the Administration, e.g. by one of the following methods:

.1 reliquefaction of vapours;

.2 thermal oxidation of vapours;

.3 pressure accumulation; or

.4 liquefied gas fuel cooling.

The method chosen shall be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming full tank at normal service pressure and the ship in idle condition, i.e. only power for domestic load is generated.

LR 6.9-01 Liquefied gas fuel tank pressure and temperature shall be controlled and maintained within the design range at all times including after activation of the safety system required in 15.2.2 for a period of minimum 15 days. The activation of the safety system alone is not deemed as an emergency situation.

6.9.1.2 Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations.

6.9.2 Design of systems

6.9.2.1 For worldwide service, the upper ambient design temperature shall be sea 32°C and air 45°C. For service in particularly hot or cold zones, these design temperatures shall be increased or decreased, to the satisfaction of the Administration.

6.9.2.2 The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere.

6.9.3 Reliquefaction systems

6.9.3.1 The reliquefaction system shall be designed and calculated according to 6.9.3.2. The system has to be sized in a sufficient way also in case of no or low consumption.

6.9.3.2 The reliquefaction system shall be arranged in one of the following ways:

.1 a direct system where evaporated fuel is compressed, condensed and returned to the fuel tanks;

.2 an indirect system where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;

.3 a combined system where evaporated fuel is compressed and condensed in a fuel/refrigerant heat exchanger and returned to the fuel tanks; or

.4 if the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases shall, as far as reasonably practicable, be disposed of without venting to atmosphere.

LR 6.9-02 Cooling water return from heat exchangers which contain fuel are not to be led into the main machinery spaces.

6.9.4 Thermal oxidation systems

6.9.4.1 Thermal oxidation can be done by either consumption of the vapours according to the regulations for consumers described in this Code or in a dedicated gas combustion unit (GCU). It shall be demonstrated that the capacity of the oxidation system is sufficient to consume the required quantity of vapours. In this regard, periods of slow steaming and/or no consumption from propulsion or other services of the ship shall be considered.

6.9.5 Compatibility

6.9.5.1 Refrigerants or auxiliary agents used for refrigeration or cooling of fuel shall be compatible with the fuel they may come in contact with (not causing any hazardous reaction or excessively corrosive products). In addition, when several refrigerants or agents are used, these shall be compatible with each other.

6.9.6 Availability of systems

6.9.6.1 The availability of the system and its supporting auxiliary services shall be such that in case of a single failure (of mechanical non-static component or a component of the control systems) the fuel tank pressure and temperature can be maintained by another service/system.

6.9.6.2 Heat exchangers that are solely necessary for maintaining the pressure and temperature of the fuel tanks within their design ranges shall have a standby heat exchanger unless they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external sources.

LR 6.9-03 The largest required capacity for pressure control is to include additional capacity to account for any system inefficiencies expected in service and any additional capacity required to deal with variations in bunkering process conditions (e.g. temperature, pressure, flow rate, etc.).

6.10 Regulations on atmospheric control within the fuel containment system

6.10.1 A piping system shall be arranged to enable each fuel tank to be safely gas-freed, and to be safely filled with fuel from a gas-free condition. The system shall be arranged to minimize the possibility of pockets of gas or air remaining after changing the atmosphere.

6.10.2 The system shall be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

6.10.3 Gas sampling points shall be provided for each fuel tank to monitor the progress of atmosphere change.

6.10.4 Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.

6.11 Regulations on atmosphere control within fuel storage hold spaces (Fuel containment systems other than type C independent tanks)

6.11.1 Interbarrier and fuel storage hold spaces associated with liquefied gas fuel containment systems requiring full or partial secondary barriers shall be inerted with a suitable dry inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation system, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days. Shorter periods may be considered by the Administration depending on the ship's service.

6.11.2 Alternatively, the spaces referred to in 6.11.1 requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation system sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the liquefied gas fuel tanks will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment for the provision of sufficient dry air of suitable quality to satisfy the expected demand shall be provided.

6.12 Regulations on environmental control of spaces surrounding type C independent tanks

6.12.1 Spaces surrounding liquefied gas fuel tanks shall be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air drying equipment. This is only applicable for liquefied gas fuel tanks where condensation and icing due to cold surfaces is an issue.

6.13 Regulations on inerting

6.13.1 Arrangements to prevent back-flow of fuel vapour into the inert gas system shall be provided as specified below.

6.13.2 To prevent the return of flammable gas to any non-hazardous spaces, the inert gas supply line shall be fitted with two shutoff valves in series with a venting valve in between (double block and bleed valves). In addition, a closable non-return valve shall be installed between the double block and bleed arrangement and the fuel system. These valves shall be located outside non-hazardous spaces.

6.13.3 Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in 6.13.2.

6.13.4 The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. shall be provided for controlling pressure in these spaces.

6.13.5 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual spaces.

6.14 Regulations on inert gas production and storage on board

LR 6.14-01 The nitrogen generator, where fitted, is to be capable of delivering high purity nitrogen in accordance with Ch 15, 2.2.1.2.5 of the FSS Code, as amended by MSC. 367(93). In addition to Ch 15, 2.2.2.4 of the FSS Code, as amended by MSC. 367(93), the system is to be fitted with automatic means to discharge 'off-spec' gas to the atmosphere during start-up and abnormal operation.

LR 6.14-02 Inert gas systems are to be so designed as to minimise the risk of ignition from the generation of static electricity by the system itself.

6.14.1 The equipment shall be capable of producing inert gas with oxygen content at no time greater than 5% by volume. A continuous-reading oxygen content meter shall be fitted to the inert gas supply from the equipment and shall be fitted with an alarm set at a maximum of 5% oxygen content by volume.

6.14.2 An inert gas system shall have pressure controls and monitoring arrangements appropriate to the fuel containment system.

6.14.3 Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine-room, the separate compartment shall be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm shall be fitted.

6.14.4 Nitrogen pipes shall only be led through well ventilated spaces. Nitrogen pipes in enclosed spaces shall:

- be fully welded;

- have only a minimum of flange connections as needed for fitting of valves; and

- be as short as possible.

7 Material and General Pipe Design

7.1 Goal

7.1.1 The goal of this chapter is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved.

7.2 Functional requirements

7.2.1 This chapter relates to functional requirements in 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10. In particular the following apply:

7.2.1.1 Fuel piping shall be capable of absorbing thermal expansion or contraction caused by extreme temperatures of the fuel without developing substantial stresses.

7.2.1.2 Provision shall be made to protect the piping, piping system and components and fuel tanks from excessive stresses due to thermal movement and from movements of the fuel tank and hull structure.

7.2.1.3 If the fuel gas contains heavier constituents that may condense in the system, means for safely removing the liquid shall be fitted.

7.2.1.4 Low temperature piping shall be thermally isolated from the adjacent hull structure, where necessary, to prevent the temperature of the hull from falling below the design temperature of the hull material.

7.3 Regulations for general pipe design

7.3.1 General

7.3.1.1 Fuel pipes and all the other piping needed for a safe and reliable operation and maintenance shall be colour marked in accordance with a standard at least equivalent to those acceptable to the Organization.[13]

7.3.1.2 Where tanks or piping are separated from the ship's structure by thermal isolation, provision shall be made for electrically bonding to the ship's structure both the piping and the tanks. All gasketed pipe joints and hose connections shall be electrically bonded.

7.3.1.3 All pipelines or components which may be isolated in a liquid full condition shall be provided with relief valves.

LR 7.3-01 All pipelines or components which may be isolated automatically due to a fire with a liquid volume of more than 0,05 m^3 entrapped shall be provided with pressure relief valves sized for a fire condition.

7.3.1.4 Pipework, which may contain low temperature fuel, shall be thermally insulated to an extent which will minimize condensation of moisture.

7.3.1.5 Piping other than fuel supply piping and cabling may be arranged in the double wall piping or duct provided that they do not create a source of ignition or compromise the integrity of the double pipe or duct. The double wall piping or duct shall only contain piping or cabling necessary for operational purposes.

7.3.2 Wall thickness

7.3.2.1 The minimum wall thickness shall be calculated as follows:

$$t = (t_0 + b + c) / (1 - a/100) \text{ (mm)}$$

where:

t_0 = theoretical thickness
$t_0 = PD / (2.0Ke + P)$ (mm)
with:

P = design pressure (MPa) referred to in 7.3.3;
D = outside diameter (mm);
K = allowable stress (N/mm^2) referred to in 7.3.4; and
e = efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, that are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognized standards. In other cases an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process;

b = allowance for bending (mm). The value of b shall be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b shall be:
$b = D \cdot t_0 / 2.5r$ (mm)
with:

r = mean radius of the bend (mm);

c = corrosion allowance (mm). If corrosion or erosion is expected the wall thickness of the piping shall be increased over that required by other design regulations. This allowance shall be consistent with the expected life of the piping; and
a = negative manufacturing tolerance for thickness (%).

7.3.2.2 The absolute minimum wall thickness shall be in accordance with a standard acceptable to the Administration.

[13] Refer to EN ISO 14726:2008 Ships and marine technology – Identification colours for the content of piping systems.

LR 7.3-02 The nominal thickness of steel pipes is to be not less than shown in *Table LR 5.1* of the Rules for Ships for Liquefied Gases. The nominal thickness of austenitic stainless steel pipes is to be not less than shown in *Pt 5, Ch 12, Table 12.10.1* of the Rules for Ships.

7.3.3 Design condition

7.3.3.1 The greater of the following design conditions shall be used for piping, piping system and components as appropriate:[14,15]

.1 for systems or components which may be separated from their relief valves and which contain only vapour at all times, vapour pressure at 45°C assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

.2 the MARVS of the fuel tanks and fuel processing systems; or

.3 the pressure setting of the associated pump or compressor discharge relief valve; or

.4 the maximum total discharge or loading head of the fuel piping system; or

.5 the relief valve setting on a pipeline system.

7.3.3.2 Piping, piping systems and components shall have a minimum design pressure of 1.0 MPa except for open ended lines where it is not to be less than 0.5 MPa.

7.3.4 Allowable stress

7.3.4.1 For pipes made of steel including stainless steel, the allowable stress to be considered in the formula of the strength thickness in 7.3.2.1 shall be the lower of the following values:

$R_m/2.7$ or $R_e/1.8$

where:

R_m = specified minimum tensile strength at room temperature (N/mm²); and

R_e = specified minimum yield stress at room temperature (N/mm²). If the stress strain curve does not show a defined yield stress, the 0.2% proof stress applies.

7.3.4.2 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads, the wall thickness shall be increased over that required by 7.3.2 or, if this is impracticable or would cause excessive local stresses, these loads shall be reduced, protected against or eliminated by other design methods. Such superimposed loads may be due to; supports, ship deflections, liquid pressure surge during transfer operations, the weight of suspended valves, reaction to loading arm connections, or otherwise.

7.3.4.3 For pipes made of materials other than steel, the allowable stress shall be considered by the Administration.

7.3.4.4 High pressure fuel piping systems shall have sufficient constructive strength. This shall be confirmed by carrying out stress analysis and taking into account:

.1 stresses due to the weight of the piping system;

.2 acceleration loads when significant; and

.3 internal pressure and loads induced by hog and sag of the ship.

7.3.4.5 When the design temperature is minus 110°C or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship shall be carried out for each branch of the piping system.

[14] Lower values of ambient temperature regarding design condition in 7.3.3.1.1 may be accepted by the Administration for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.

[15] For ships on voyages of restricted duration, P_0 may be calculated based on the actual pressure rise during the voyage and account may be taken of any thermal insulation of the tank. Reference is made to the *Application of amendments to gas carrier codes concerning type C tank loading limits (SIGTTO/IACS).*

LR 7.3-03 The stress analysis is to be undertaken according to a standard acceptable to LR. Tank connection space integrity calculations are to also be included, *see* LR 6.3-01 and LR 6.3-02.

7.3.5 Flexibility of piping

7.3.5.1 The arrangement and installation of fuel piping shall provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking potential for fatigue into account.

LR 7.3-04 Fatigue analysis is required for all pressurised low-flashpoint fuel piping arrangements subject to vibration or pulsating pressure where failure of the pipe or its connection or a component would be the cause of a prime mover being unavailable. The analysis is to recognise the pressures and fluctuating stresses that the piping system may be subject to in normal service.

7.3.6 Piping fabrication and joining details

7.3.6.1 Flanges, valves and other fittings shall comply with a standard acceptable to the Administration, taking into account the design pressure defined in 7.3.3.1. For bellows and expansion joints used in vapour service, a lower minimum design pressure than defined in 7.3.3.1 may be accepted.

7.3.6.2 All valves and expansion joints used in high pressure fuel piping systems shall be approved according to a standard acceptable to the Administration.

7.3.6.3 The piping system shall be joined by welding with a minimum of flange connections. Gaskets shall be protected against blow-out.

7.3.6.4 Piping fabrication and joining details shall comply with the following:

7.3.6.4.1 Direct connections

.1 Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures colder than minus 10°C, butt welds shall be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of minus 10°C or colder, backing rings shall be removed.

.2 Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, shall only be used for instrument lines and open-ended lines with an external diameter of 50 mm or less and design temperatures not colder than minus 55°C.

.3 Screwed couplings complying with recognized standards shall only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

7.3.6.4.2 *Flanged connections*

.1 Flanges in flange connections shall be of the welded neck, slip-on or socket welded type; and

.2 For all piping except open ended, the following restrictions apply:

.1 For design temperatures colder than minus 55°C, only welded neck flanges shall be used; and

.2 For design temperatures colder than minus 10°C, slip-on flanges shall not be used in nominal sizes above 100 mm and socket welded flanges shall not be used in nominal sizes above 50 mm.

7.3.6.4.3 *Expansion joints*

Where bellows and expansion joints are provided in accordance with 7.3.6.1 the following apply:

.1 if necessary, bellows shall be protected against icing;

.2 slip joints shall not be used except within the liquefied gas fuel storage tanks; and

.3 bellows shall normally not be arranged in enclosed spaces.

7.3.6.4.4 Other connections

Piping connections shall be joined in accordance with 7.3.6.4.1 to 7.3.6.4.3 but for other exceptional cases the Administration may consider alternative arrangements.

7.4 Regulations for materials

LR 7.4-01 The Materials to be used in the construction of gas bunkering stations, gas storage tanks including piping, gas process equipment and gas-fuelled machinery have to be considered, as appropriate, in the risk assessment (*see* Chapter 4.2), and are to be acceptable to LR. The materials also need to satisfy the requirements of this Chapter.

7.4.1 Metallic materials

7.4.1.1 Materials for fuel containment and piping systems shall comply with the minimum regulations given in the following tables:

Table 7.1: Plates, pipes (seamless and welded), sections and forgings for fuel tanks and process pressure vessels for design temperatures not lower than 0°C.

Table 7.2: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below 0°C and down to minus 55°C.

Table 7.3: Plates, sections and forgings for fuel tanks, secondary barriers and process pressure vessels for design temperatures below minus 55°C and down to minus 165°C.

Table 7.4: Pipes (seamless and welded), forgings and castings for fuel and process piping for design temperatures below 0°C and down to minus 165°C.

Table 7.5: Plates and sections for hull structures required by 6.4.13.1.1.2.

Table 7.1

PLATES, PIPES (SEAMLESS AND WELDED) [1, 2], SECTIONS AND FORGINGS FOR FUEL TANKS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES NOT LOWER THAN 0°C		
CHEMICAL COMPOSITION AND HEAT TREATMENT		
◆ Carbon-manganese steel		
◆ Fully killed fine grain steel		
◆ Small additions of alloying elements by agreement with the Administration		
◆ Composition limits to be approved by the Administration		
◆ Normalized, or quenched and tempered[4]		
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS		
Sampling frequency		
◆ Plates	Each "piece" to be tested	
◆ Sections and forgings	Each "batch" to be tested.	
Mechanical properties		
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [5]	
Toughness (Charpy V-notch test)		
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J	
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J	
◆ Test temperature	Thickness t (mm)	Test temperature (°C)
	$T \leq 20$	0
	$20 < t \leq 40$[3]	-20

Notes

1. For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by the Administration.

2. Charpy V-notch impact tests are not required for pipes.

3. This Table is generally applicable for material thicknesses up to 40 mm. Proposals for greater thicknesses shall be approved by the Administration.

4. A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.

5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Table LR 7.1

PLATES, PIPES (SEAMLESS AND WELDED) [1, 2], SECTIONS AND FORGINGS FOR FUEL TANKS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES NOT LOWER THAN 0°C		
CHEMICAL COMPOSITION AND HEAT TREATMENT (*See* LR 2)		
◆ Carbon-manganese steel		
◆ Fully killed fine grain steel (*See* LR 4)		
◆ Small additions of alloying elements by agreement with the Administration		
◆ Composition limits to be approved by the Administration		
◆ Normalized, or quenched and tempered[4] (*See* LR 4)		
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS		
Sampling frequency		
◆ Plates	Each "piece" to be tested	
◆ Sections and forgings	Each "batch" to be tested.	
Mechanical properties		
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^2 [5] (*See* LR 4)	
Toughness (Charpy V-notch test)		
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J	
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J	
◆ Test temperature	Thickness t (mm)	Test temperature (°C)
	$T \leq 20$	0 (*See* LR 4)
	$20 < t \leq 40$[3]	-20

Notes

1. For seamless pipes and fittings normal practice applies. The use of longitudinally and spirally welded pipes shall be specially approved by the Administration. (*See* LR 1)

2. Charpy V-notch impact tests are not required for pipes. (*See* LR 5)

3. This Table is generally applicable for material thicknesses up to 40 mm. Proposals for greater thicknesses shall be approved by the Administration.

4. A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.

5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones. (*See* LR 3)

LR 1 Welded pressure pipes complying with the requirements of Chapter 6 of the Rules for Materials are acceptable, and special approval is not required. (*See* LR 4).

LR 2 Generally, the chemical composition and mechanical properties, yield stress, tensile strength and elongation are to comply with the requirements for appropriate grades as given in the Rules for Materials.

LR 3 Stress corrosion cracking can occur in tanks carrying natural gas contaminated with hydrogen sulphide. In order to minimise this risk, it is recommended that tanks intended for the carriage of this substance are constructed in steel with a specified minimum tensile strength not exceeding 410 N/mm^2. If steels of higher tensile strength are used, it is recommended that the completed fuel tanks or process pressure vessels are given a suitable stress relieving heat treatment in order to reduce the hardness of the weld metal and heat affected zone to 250 Vickers Pyramid Number maximum (HV).

LR 4 Stress corrosion cracking can occur in tanks carrying natural gas contaminated with hydrogen sulphide. Impact tests are to be made at –20°C for all thicknesses. For pipes, test specimens are to be taken in the longitudinal direction and are to have an average energy value not less than 41J.

LR 5 Charpy V-notch impact tests are to be carried out when required by the Rules for Materials.

Table 7.2

PLATES, SECTIONS AND FORGINGS [1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO MINUS 55°C **Maximum thickness 25 mm [2]**
CHEMICAL COMPOSITION AND HEAT TREATMENT
◆ Carbon-manganese steel
◆ Fully killed, aluminium treated fine grain steel
◆ Chemical composition (ladle analysis)

C	Mn	Si	S	P
0.16% max. [3]	0.70-1.60%	0.10-0.50%	0.025% max.	0.025% max.
Optional additions: Alloys and grain refining elements may be generally in accordance with the following				
Ni	Cr	Mo	Cu	Nb
0.80% max.	0.25% max.	0.08% max.	0.35% max.	0.05% max.
V				
0.10% max.				
Al content total 0.020% min. (Acid soluble 0.015% min.)				

◆ Normalized, or quenched and tempered [4]	
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS	
Sampling frequency	
◆ Plates	Each 'piece' to be tested
◆ Sections and forgings	Each 'batch' to be tested
Mechanical properties	
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^{2} [5]
Toughness (Charpy V-notch test)	
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J
◆ Test temperature	5°C below the design temperature or -20°C whichever is lower

Notes

1. The Charpy V-notch and chemistry regulations for forgings may be specially considered by the Administration.
2. For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below design temperature or -20°C whichever is lower
$30 < t \leq 35$	15°C below design temperature or -20°C whichever is lower

	35 < t ≤ 40	20°C below design temperature
	40 < t	Temperature approved by the Administration

The impact energy value shall be in accordance with the table for the applicable type of test specimen. Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C whichever is lower. For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank-shell thickness.

3. By special agreement with the Administration, the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40°C

4. A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.

5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

Guidance:

For materials exceeding 25 mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steels or steels in accordance with table 7.3 may be necessary.

Table LR 7.2

PLATES, SECTIONS AND FORGINGS [1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO MINUS 55°C **Maximum thickness 25 mm [2]**						
CHEMICAL COMPOSITION AND HEAT TREATMENT						
◆ Carbon-manganese steel						
◆ Fully killed, aluminium treated fine grain steel						
◆ Chemical composition (ladle analysis)						
	C	Mn	Si	S	P	
	0.16% max. [3]	0.70-1.60%	0.10-0.50%	0.025% max.	0.025% max.	
	Optional additions: Alloys and grain refining elements may be generally in accordance with the following					
	Ni	Cr	Mo	Cu	Nb	
	0.80% max.	0.25% max.	0.08% max.	0.35% max.	0.05% max.	
	V					
	0.10% max.					
	Al content total 0.020% min. (Acid soluble 0.015% min.)					
◆ Normalized, or quenched and tempered [4]						
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS						
Sampling frequency						
◆ Plates	Each 'piece' to be tested					
◆ Sections and forgings	Each 'batch' to be tested					
Mechanical properties						
◆ Tensile properties	Specified minimum yield stress not to exceed 410 N/mm^{2} [5]					
Toughness (Charpy V-notch test)						

◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J
◆ Test temperature	5°C below the design temperature or -20°C whichever is lower

Notes

1. The Charpy V-notch and chemistry regulations for forgings may be specially considered by the Administration.

2. For material thickness of more than 25 mm, Charpy V-notch tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below design temperature or -20°C whichever is lower
$30 < t \leq 35$	15°C below design temperature or -20°C whichever is lower
$35 < t \leq 40$	20°C below design temperature
$40 < t$	Temperature approved by the Administration (*See* LR 1)

The impact energy value shall be in accordance with the table for the applicable type of test specimen. Materials for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C whichever is lower. For thermally stress relieved reinforcements and other fittings, the test temperature shall be the same as that required for the adjacent tank-shell thickness.

3. By special agreement with the Administration, the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40°C

4. A controlled rolling procedure or thermo-mechanical controlled processing (TMCP) may be used as an alternative.

5. Materials with specified minimum yield stress exceeding 410 N/mm^2 may be approved by the Administration. For these materials, particular attention shall be given to the hardness of the welded and heat affected zones.

LR 1 The temperature requirement is subject to agreement with LR.

LR 2 Stress corrosion cracking can occur in tanks carrying natural gas contaminated with hydrogen sulphide, *see* 17.12 of the Rules for Ships for Liquefied Gases. If steels of higher tensile strength are used, it is recommended that the completed fuel tanks or process pressure vessels are given a suitable stress relieving heat treatment in order to reduce the hardness of the weld metal and heat affected zone to 250 HV maximum.

Guidance:

For materials exceeding 25 mm in thickness for which the test temperature is -60°C or lower, the application of specially treated steels or steels in accordance with table 7.3 may be necessary.

Table 7.3

PLATES, SECTIONS AND FORGINGS [1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW MINUS 55°C AND DOWN TO MINUS 165°C[2]		
Maximum thickness 25 mm [3, 4]		
Minimum design temp. (°C)	Chemical composition[5] and heat treatment	Impact test temp. (°C)
-60	1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP [see note 6]	-65
-65	2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6, 7]	-70
-90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6, 7]	-95

-105	5% nickel steel – normalized or normalized and tempered or quenched and tempered[6, 7 and 8]	-110
-165	9% nickel steel – double normalized and tempered or quenched and tempered[6]	-196
-165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated[9]	-196
-165	Aluminium alloys; such as type 5083 annealed	Not required
-165	Austenitic Fe-Ni alloy (36% nickel) Heat treatment as agreed	Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS

Sampling frequency	
◆ Plates	Each 'piece' to be tested
◆ Sections and forgings	Each 'batch' to be tested
Toughness (Charpy V-notch test)	
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J

Notes

1. The impact test required for forgings used in critical applications shall be subject to special consideration by the Administration.
2. The regulations for design temperatures below –165°C shall be specially agreed with the Administration.
3. For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thicknesses greater than 25 mm, the impact tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below design temperature
$30 < t \leq 35$	15°C below design temperature
$35 < t \leq 40$	20°C below design temperature

The energy value shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values shall be specially considered.

4. For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.
5. The chemical composition limits shall be in accordance with recognized standards.
6. Thermo-mechanical controlled processing (TMCP) nickel steels will be subject to acceptance by the Administration.
7. A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Administration.
8. A specially heat treated 5% nickel steel, for example triple heat treated 5% nickel steel, may be used down to –165°C, provided that the impact tests are carried out at –196°C.
9. The impact test may be omitted subject to agreement with the Administration.

Table LR 7.3

PLATES, SECTIONS AND FORGINGS [1] FOR FUEL TANKS, SECONDARY BARRIERS AND PROCESS PRESSURE VESSELS FOR DESIGN TEMPERATURES BELOW MINUS 55°C AND DOWN TO MINUS 165°C[2] Maximum thickness 25 mm [3, 4]		
Minimum design temp. (°C)	Chemical composition[5] and heat treatment	Impact test temp. (°C)

-60	1.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP see note 6	-65
-65	2.25% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6, 7]	-70
-90	3.5% nickel steel – normalized or normalized and tempered or quenched and tempered or TMCP[6, 7]	-95
-105	5% nickel steel – normalized or normalized and tempered or quenched and tempered[6, 7 and 8]	-110
-165	9% nickel steel – double normalized and tempered or quenched and tempered[6]	-196
-165	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347 solution treated[9] (*See* LR 4)	-196
-165	Aluminium alloys; such as type 5083 annealed	Not required
-165	Austenitic Fe-Ni alloy (36% nickel) Heat treatment as agreed	Not required

TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS

Sampling frequency	
◆ Plates	Each 'piece' to be tested
◆ Sections and forgings	Each 'batch' to be tested

Toughness (Charpy V-notch test)	
◆ Plates	Transverse test pieces. Minimum average energy value (KV) 27J
◆ Sections and forgings	Longitudinal test pieces. Minimum average energy (KV) 41J

Notes

1. The impact test required for forgings used in critical applications shall be subject to special consideration by the Administration.

2. The regulations for design temperatures below –165°C shall be specially agreed with the Administration.

3. For materials 1.5% Ni, 2.25% Ni, 3.5% Ni and 5% Ni, with thicknesses greater than 25 mm, the impact tests shall be conducted as follows:

Material thickness (mm)	Test temperature (°C)
$25 < t \leq 30$	10°C below design temperature
$30 < t \leq 35$	15°C below design temperature
$35 < t \leq 40$	20°C below design temperature

The energy value shall be in accordance with the table for the applicable type of test specimen. For material thickness of more than 40 mm, the Charpy V-notch values shall be specially considered.

4. For 9% Ni steels, austenitic stainless steels and aluminium alloys, thickness greater than 25 mm may be used.

5. The chemical composition limits shall be in accordance with recognized standards.

6. Thermo-mechanical controlled processing (TMCP) nickel steels will be subject to acceptance by the Administration.

7. A lower minimum design temperature for quenched and tempered steels may be specially agreed with the Administration.

8. A specially heat treated 5% nickel steel, for example triple heat treated 5% nickel steel, may be used down to –165°C, provided that the impact tests are carried out at –196°C.

9. The impact test may be omitted subject to agreement with the Administration. (*See* LR 2)

LR 1 In no case should the test temperature exceed that shown in the main Table above.

LR 2	Generally, impact tests are not required.
LR 3	Stress corrosion cracking can occur in tanks carrying natural gas contaminated with hydrogen sulphide, *see* 17.12 of the Rules for Ships for Liquefied Gases. If steels of higher tensile strength are used, it is recommended that the completed fuel tanks or process pressure vessels are given a suitable stress relieving heat treatment in order to reduce the hardness of the weld metal and heat affected zone to 250 HV maximum.
LR 4	Grades 304 and 316 are not to be used for welded construction.

Table 7.4

PIPES (SEAMLESS AND WELDED)[1], FORGINGS[2] AND CASTINGS[2] FOR FUEL AND PROCESS PIPING FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO MINUS 165°C[3] — Maximum thickness 25 mm			
Minimum design temp.(°C)	Chemical composition[5] and heat treatment	Impact test	
		Test temp. (°C)	Minimum average energy (KV)
-55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed.[6]	See note 4	27
-65	2.25% nickel steel. Normalized, Normalized and tempered or quenched and tempered.[6]	-70	34
-90	3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered.[6]	-95	34
-165	9% nickel steel[7]. Double normalized and tempered or quenched and tempered.	-196	41
	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated.[8]	-196	41
	Aluminium alloys; such as type 5083 annealed		Not required
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS			
Sampling frequency			
◆ Each 'batch' to be tested.			
Toughness (Charpy V-notch test)			
◆ Impact test: Longitudinal test pieces			

Notes

1. The use of longitudinally or spirally welded pipes shall be specially approved by the Administration.
2. The regulations for forgings and castings may be subject to special consideration by the Administration.
3. The regulations for design temperatures below -165°C shall be specially agreed with the Administration.
4. The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.
5. The composition limits shall be in accordance with Recognized Standards.
6. A lower design temperature may be specially agreed with the Administration for quenched and tempered materials.
7. This chemical composition is not suitable for castings.
8. Impact tests may be omitted subject to agreement with the Administration.

Table LR 7.4

PIPES (SEAMLESS AND WELDED)[1], FORGINGS[2] AND CASTINGS[2] FOR FUEL AND PROCESS PIPING FOR DESIGN TEMPERATURES BELOW 0°C AND DOWN TO MINUS 165°C[3] Maximum thickness 25 mm			
Minimum design temp.(°C)	Chemical composition[5] and heat treatment	Impact test	
		Test temp. (°C)	Minimum average energy (KV)
-55	Carbon-manganese steel. Fully killed fine grain. Normalized or as agreed.[6]	See note 4	27
-65	2.25% nickel steel. Normalized, Normalized and tempered or quenched and tempered.[6]	-70	34
-90	3.5% nickel steel. Normalized, Normalized and tempered or quenched and tempered.[6]	-95	34
-165	9% nickel steel[7]. Double normalized and tempered or quenched and tempered.	-196	41
	Austenitic steels, such as types 304, 304L, 316, 316L, 321 and 347. Solution treated.[8] (*See* LR 3)	-196	41
	Aluminium alloys; such as type 5083 annealed		Not required
TENSILE AND TOUGHNESS (IMPACT) TEST REGULATIONS			
Sampling frequency			
◆ Each 'batch' to be tested.			
Toughness (Charpy V-notch test)			
◆ Impact test: Longitudinal test pieces			

Notes

1. The use of longitudinally or spirally welded pipes shall be specially approved by the Administration. (*See* LR 1)

2. The regulations for forgings and castings may be subject to special consideration by the Administration.

3. The regulations for design temperatures below -165°C shall be specially agreed with the Administration.

4. The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.

5. The composition limits shall be in accordance with Recognized Standards.

6. A lower design temperature may be specially agreed with the Administration for quenched and tempered materials.

7. This chemical composition is not suitable for castings.

8. Impact tests may be omitted subject to agreement with the Administration. (*See* LR 2)

LR 1 Welded pressure pipes complying with the requirements of Chapter 6 of the Rules for Materials are acceptable and special approval is not required.

LR 2 Impact tests are not required except for austenitic steel castings intended for applications where the design temperature is lower than –55°C.

LR 3 Grades 304 and 316 are not to be used for welded pipework.

Table 7.5

PLATES AND SECTIONS FOR HULL STRUCTURES REQUIRED BY 6.4.13.1.1.2								
Minimum design temperature of hull structure (°C)	Maximum thickness (mm) for steel grades							
	A	B	D	E	AH	DH	EH	FH
0 and above	Recognized Standards							
down to -5	15	25	30	50	25	45	50	50
down to -10	x	20	25	50	20	40	50	50
down to -20	x	x	20	50	x	30	50	50
down to -30	x	x	x	40	x	20	40	50
Below -30	In accordance with table 7.2 except that the thickness limitation given in table 7.2 and in footnote 2 of that table does not apply.							
Notes 'x' means steel grade not to be used.								

LR 7.4–02 The materials of the hull structure are to comply with the requirements of the Rules for Materials. The requirements of Pt 3, Ch 2 of the Rules for Ships are also to be complied with, except as indicated otherwise by the requirements of these Rules.

LR 7.4–03 Where higher tensile steel is used in the hull structure, the scantling and arrangements are to be as required by Part 3 and Part 4 of the Rules for Ships.

LR 7.4–04 Plans illustrating the means of protection for the ship steelwork, e.g. drip trays, cladding, etc., at bunkering manifolds; deck tanks, fuel handling system, etc., are to be submitted for approval.

7.4.1.2 Materials having a melting point below 925°C shall not be used for piping outside the fuel tanks.

7.4.1.3 For CNG tanks, the use of materials not covered above may be specially considered by the Administration.

7.4.1.4 Where required the outer pipe or duct containing high pressure gas in the inner pipe shall as a minimum fulfil the material regulations for pipe materials with design temperature down to minus 55°C in table 7.4.

7.4.1.5 The outer pipe or duct around liquefied gas fuel pipes shall as a minimum fulfil the material regulations for pipe materials with design temperature down to minus 165°C in table 7.4.

8 Bunkering

8.1 Goal

8.1.1 The goal of this chapter is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.

8.2 Functional requirements

8.2.1 This chapter relates to functional requirements in 3.2.1 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply:

8.2.1.1 The piping system for transfer of fuel to the storage tank shall be designed such that any leakage from the piping system cannot cause danger to personnel, the environment or the ship.

8.3 Regulations for bunkering station

8.3.1 General

8.3.1.1 The bunkering station shall be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations shall be subject to special consideration within the risk assessment.

LR 8.3-01 The special consideration shall as a minimum include, but not be restricted to, the following design features:

- segregation from other areas on the ship;

- hazardous area plans for the ship;
- requirements for forced ventilation;
- requirements for leakage detection (e.g. gas detection and low temperature detection);
- safety actions related to leakage detection (e.g. gas detection and low temperature detection);
- access to bunkering station from non-hazardous areas through airlocks; and
- monitoring of bunkering station by direct line of sight or by CCTV.

8.3.1.2 Connections and piping shall be so positioned and arranged that any damage to the fuel piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled gas discharge.

8.3.1.3 Arrangements shall be made for safe management of any spilled fuel.

LR 8.3-02 Physical arrangements are to be provided for safe management of any spilled fuel during bunkering. This is to include spray shields as appropriate and drip trays fitted below bunkering connections and where leakage may occur. Each drip tray is to be:

(a). made of suitable material to hold spills (e.g. stainless steel);

(b). thermally isolated from the ship’s structure;

(c). fitted with a means to dispose of spills safely, such as draining overboard by a fixed or temporary pipe that has a submerged end;

(d). fitted with a drain valve to enable rain water to be drained over the ship’s side;

(e). of sufficient capacity to handle reasonably foreseeable leakage.

(f). fitted with a temperature sensor to detect low temperature and provide an audible and visual alarm at the bunkering control station.

8.3.1.4 Suitable means shall be provided to relieve the pressure and remove liquid contents from pump suctions and bunker lines. Liquid is to be discharged to the liquefied gas fuel tanks or other suitable location.

8.3.1.5 The surrounding hull or deck structures shall not be exposed to unacceptable cooling, in case of leakage of fuel.

LR 8.3-03 Suitable arrangements are to be provided to protect the hull structure from potential spillages during the bunkering operation (e.g. water curtain or stainless steel sheath/plating).

8.3.1.6 For CNG bunkering stations, low temperature steel shielding shall be considered to determine if the escape of cold jets impinging on surrounding hull structure is possible.

8.3.2 Ships' fuel hoses

8.3.2.1 Liquid and vapour hoses used for fuel transfer shall be compatible with the fuel and suitable for the fuel temperature.

8.3.2.2 Hoses subject to tank pressure, or the discharge pressure of pumps or vapour compressors, shall be designed for a bursting pressure not less than five times the maximum pressure the hose can be subjected to during bunkering.

LR 8.3-04 The hoses referred to are those used for the bunkering of fuel. The design, construction and testing of such hoses are to be in accordance with the requirements of the relevant National Administration and/or Port Authority.

8.4 Regulations for manifold

8.4.1 The bunkering manifold shall be designed to withstand the external loads during bunkering. The connections at the bunkering station shall be of dry-disconnect type equipped with additional safety dry break-away coupling/ self-sealing quick release. The couplings shall be of a standard type.

8.5 Regulations for bunkering system

8.5.1 An arrangement for purging fuel bunkering lines with inert gas shall be provided.

8.5.2 The bunkering system shall be so arranged that no gas is discharged to the atmosphere during filling of storage tanks.

8.5.3 A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve shall be fitted in every bunkering line close to the connecting point. It shall be possible to operate the remote valve in the control location for bunkering operations and/or from another safe location.

8.5.4 Means shall be provided for draining any fuel from the bunkering pipes upon completion of operation.

8.5.5 Bunkering lines shall be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes shall be free of gas, unless the consequences of not gas freeing are evaluated and approved.

8.5.6 In case bunkering lines are arranged with a cross-over it shall be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering.

8.5.7 A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source shall be fitted.

8.5.8 If not demonstrated to be required at a higher value due to pressure surge considerations a default time as calculated in accordance with 16.7.3.7 from the trigger of the alarm to full closure of the remote operated valve required by 8.5.3 shall be adjusted.

9 Fuel Supply to Consumers

9.1 Goal

The goal of this chapter is to ensure safe and reliable distribution of fuel to the consumers.

9.2 Functional requirements

This chapter is related to functional requirements in 3.2.1 to 3.2.6, 3.2.8 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply:

.1 the fuel supply system shall be so arranged that the consequences of any release of fuel will be minimized, while providing safe access for operation and inspection;

.2 the piping system for fuel transfer to the consumers shall be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and

.3 fuel lines outside the machinery spaces shall be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

9.3 Regulations on redundancy of fuel supply

9.3.1 For single fuel installations the fuel supply system shall be arranged with full redundancy and segregation all the way from the fuel tanks to the consumer, so that a leakage in one system does not lead to an unacceptable loss of power.

LR 9.3-01 For single fuel installations, a system dependability assessment is to be undertaken. The objectives of the assessment are to:

(a) demonstrate the dependability of the system during all normal and reasonably foreseeable abnormal conditions where essential services are reliant upon the system for their intended operation; and,

(b) demonstrate that an appropriate level of dependability is achieved that is commensurate with conventional oil fuelled machinery.

The scope of the assessment is to consider:

(a) the redundancy of fuel storage and supply; and,

(b) the reliability and availability of machinery, equipment and components to maintain essential services.

The assessment is to be undertaken to a recognised Standard acceptable to LR, such as IEC 60300-3-1, Dependability management Part 3-1: Application guide – Analysis techniques for dependability – Guide on methodology.

9.3.2 For single fuel installations, the fuel storage shall be divided between two or more tanks. The tanks shall be located in separate compartments.

9.3.3 For type C tank only, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.

9.4 Regulations on safety functions of gas supply system

9.4.1 Fuel storage tank inlets and outlets shall be provided with valves located as close to the tank as possible. Valves required to be operated during normal operation[16] which are not accessible shall be remotely operated. Tank valves whether accessible or not shall be automatically operated when the safety system required in 15.2.2 is activated.

9.4.2 The main gas supply line to each gas consumer or set of consumers shall be equipped with a manually operated stop valve and an automatically operated "master gas fuel valve" coupled in series or a combined manually and automatically operated valve. The valves shall be situated in the part of the piping that is outside the machinery space containing gas consumers, and placed as near as possible to the installation for heating the gas, if fitted. The master gas fuel valve shall automatically cut off the gas supply when activated by the safety system required in 15.2.2.

9.4.3 The automatic master gas fuel valve shall be operable from safe locations on escape routes inside a machinery space containing a gas consumer, the engine control room, if applicable; outside the machinery space, and from the navigation bridge.

9.4.4 Each gas consumer shall be provided with "double block and bleed" valves arrangement. These valves shall be arranged as outlined in .1 or .2 so that when the safety system required in 15.2.2 is activated this will cause the shutoff valves that are in series to close automatically and the bleed valve to open automatically and:

.1 the two shutoff valves shall be in series in the gas fuel pipe to the gas consuming equipment. The bleed valve shall be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series; or

.2 the function of one of the shutoff valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

9.4.5 The two valves shall be of the fail-to-close type, while the ventilation valve shall be fail-to-open.

9.4.6 The double block and bleed valves shall also be used for normal stop of the engine.

9.4.7 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve shall be automatically ventilated assuming reverse flow from the engine to the pipe.

LR 9.4-01 There shall be separate vent lines from areas such as gas fuel tanks and gas consumers (engines etc.) that are independent of each other. Bleed lines shall also be independent of the vent lines. Such vent and bleed lines shall not be connected to a common header unless they are from a same area.

9.4.8 There shall be one manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engine.

9.4.9 For single-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined.

9.4.10 For each main gas supply line entering an ESD protected machinery space, and each gas supply line to high pressure installations means shall be provided for rapid detection of a rupture in the gas line in the engine-room. When rupture is detected a valve shall be automatically shut off.[17] This valve shall be located in the gas supply line before it enters the engine-room or as close as possible to the point of entry inside the engine-room. It can be a separate valve or combined with other functions, e.g. the master valve.

9.5 Regulations for fuel distribution outside of machinery space

9.5.1 Where fuel pipes pass through enclosed spaces in the ship, they shall be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system shall be mechanically underpressure ventilated with 30 air changes per hour, and gas detection as required in 15.8 shall be provided. Other solutions providing an equivalent safety level may also be accepted by the Administration.

9.5.2 The requirement in 9.5.1 need not be applied for fully welded fuel gas vent pipes led through mechanically ventilated spaces.

9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces

9.6.1 Fuel piping in gas-safe machinery spaces shall be completely enclosed by a double pipe or duct fulfilling one of the following conditions:

.1 the gas piping shall be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes shall be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms

[16] Normal operation in this context is when gas is supplied to consumers and during bunkering operations.
[17] The shutdown should be time delayed to prevent shutdown due to transient load variations.

shall be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas, the system shall be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or

.2 the gas fuel piping shall be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct shall be equipped with mechanical underpressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors shall comply with the required explosion protection in the installation area. The ventilation outlet shall be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited; or

.3 other solutions providing an equivalent safety level may also be accepted by the Administration.

9.6.2 The connecting of gas piping and ducting to the gas injection valves shall be completely covered by the ducting. The arrangement shall facilitate replacement and/or overhaul of injection valves and cylinder covers. The double ducting is also required for all gas pipes on the engine itself, until gas is injected into the chamber.[18]

9.7 Regulations for gas fuel supply to consumers in ESD-protected machinery spaces

9.7.1 The pressure in the gas fuel supply system shall not exceed 1.0 MPa.

9.7.2 The gas fuel supply lines shall have a design pressure not less than 1.0 MPa.

9.8 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage

9.8.1 The design pressure of the outer pipe or duct of fuel systems shall not be less than the maximum working pressure of the inner pipe. Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

9.8.2 For high-pressure fuel piping the design pressure of the ducting shall be taken as the higher of the following:

.1 the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

.2 local instantaneous peak pressure in way of the rupture: this pressure shall be taken as the critical pressure given by the following expression:

$$p = p_0\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where:

p_0 = maximum working pressure of the inner pipe

$k = C_p/C_v$ constant pressure specific heat divided by the constant volume specific heat

$k = 1.31$ *for* CH_4

The tangential membrane stress of a straight pipe shall not exceed the tensile strength divided by 1.5 ($R_m/1.5$) when subjected to the above pressures. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports shall then be submitted.

9.8.3 Verification of the strength shall be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

9.8.4 For low pressure fuel piping the duct shall be dimensioned for a design pressure not less than the maximum working pressure of the fuel pipes. The duct shall be pressure tested to show that it can withstand the expected maximum pressure at fuel pipe rupture.

[18] If gas is supplied into the air inlet directly on each individual cylinder during air intake to the cylinder on a low pressure engine, such that a single failure will not lead to release of fuel gas into the machinery space, double ducting may be omitted on the air inlet pipe.

9.9 Regulations for compressors and pumps

9.9.1 If compressors or pumps are driven by shafting passing through a bulkhead or deck, the bulkhead penetration shall be of gastight type.

9.9.2 Compressors and pumps shall be suitable for their intended purpose. All equipment and machinery shall be such as to be adequately tested to ensure suitability for use within a marine environment. Such items to be considered would include, but not be limited to:

.1 environmental;

.2 shipboard vibrations and accelerations;

.3 effects of pitch, heave and roll motions, etc.; and

.4 gas composition.

9.9.3 Arrangements shall be made to ensure that under no circumstances liquefied gas can be introduced in the gas control section or gas-fuelled machinery, unless the machinery is designed to operate with gas in liquid state.

9.9.4 Compressors and pumps shall be fitted with accessories and instrumentation necessary for efficient and reliable function.

LR 9.9-01 Each size and type of liquefied fuel gas pump is to be approved through prototype testing and is to include a hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. In addition, for shaft driven deep well pumps, a spin test to demonstrate satisfactory operation of bearing clearances, wear rings and sealing arrangements is to be carried out at the minimum design temperature. The full length of shafting is not required for the spin test, but must be of sufficient length to include at least one bearing and sealing arrangement. On completion of testing, the pump is to be opened out for examination. Prototype testing is to be completed to the satisfaction of the LR Surveyor. In lieu of prototype testing, satisfactory in-service experience of an existing pump design approved by a Classification Society submitted by the manufacturer may be considered.

LR 9.9-02 All liquefied fuel gas pumps are to be tested at the manufacturer's works to the satisfaction of the LR Surveyor. Testing is to include a hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. For submerged electric motor driven pumps, the capacity test is to be carried out with the design medium or with a medium below the minimum working temperature. For shaft driven deep well pumps, the capacity test may be carried out with water. Alternatively, if so requested by the relevant manufacturer, the certification of a pump may be issued subject to the following:

(a) the pump has been approved in accordance with the requirements in LR 9.9-01;

(b) the manufacturer has a recognised quality system that has been assessed and certified by LR in accordance with the requirements of Pt 5, Ch 1,6 of the Rules for Ships; and,

(c) a quality control plan is submitted which contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1,5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

10 Power Generation Including Propulsion and Other Gas Consumers

10.1 Goal

10.1.1 The goal of this chapter is to provide safe and reliable delivery of mechanical, electrical or thermal energy.

LR 10.1-01 In the context of 10.1.1, electrical includes control, alarm and safety systems associated with power generation and propulsion, *see also* **LR 2.1-02.**

10.2 Functional requirements

This chapter is related to functional requirements in 3.2.1, 3.2.11, 3.2.13, 3.2.16 and 3.2.17. In particular the following apply:

.1 the exhaust systems shall be configured to prevent any accumulation of un-burnt gaseous fuel;

.2 unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture shall be fitted with suitable

pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

.3 the explosion venting shall be led away from where personnel may normally be present; and

.4 all gas consumers shall have a separate exhaust system.

10.3 Regulations for internal combustion engines of piston type

10.3.1 General

10.3.1.1 The exhaust system shall be equipped with explosion relief ventilation sufficiently dimensioned to prevent excessive explosion pressures in the event of ignition failure of one cylinder followed by ignition of the unburned gas in the system.

LR 10.3-01 Arrangements are to be provided to enable purging of the exhaust system before the starting of an engine, after failure to start and following loss of ignition during operation of the engine. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

10.3.1.2 For engines where the space below the piston is in direct communication with the crankcase a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase shall be carried out and reflected in the safety concept of the engine.

LR 10.3-02 The safety concept and corresponding arrangements for prevention of crankcase explosions is to be documented and submitted for consideration and acceptance by LR.

LR 10.3-03 The safety concept is to demonstrate that all potential hazards associated with gas accumulation in the crankcase have been considered and shall include but is not limited to the following:

(a) Engine type, i.e. trunk piston or cross head, etc.

(b) The type of engine cycle employed, i.e. diesel, Otto, etc.

(c) Sources of ignition.

(d) Gas detection requirements including type of detection system, sampling rates, etc.

(e) The potential hazard when new and during service when sealing components become worn.

(f) Cause and effect matrix.

(g) Requirements for inerting the crankcase.

LR 10.3-04 Where trunk piston type engines are used, a means of injecting inert gas into the crankcase is to be provided.

LR 10.3-05 When gas is supplied in a mixture with air through a common manifold, flame arresters shall be installed before each cylinder head. The inlet system is to be designed to withstand explosion of a gas-air mixture by means of explosion relief venting or having sufficient strength to contain a worst-case explosion. This requirement may be omitted if the gas concentration within the manifolds is controlled and if combustion of an unburnt mixture within the manifolds can be eliminated.

10.3.1.3 Each engine other than two-stroke crosshead diesel engines shall be fitted with vent systems independent of other engines for crankcases and sumps.

LR 10.3-06 The outlet of the vent system of each engine is to be led to a safe location in the open air through a flame arrestor.

10.3.1.4 Where gas can leak directly into the auxiliary system medium (lubricating oil, cooling water), an appropriate means shall be fitted after the engine outlet to extract gas in order to prevent gas dispersion. The gas extracted from auxiliary systems media shall be vented to a safe location in the atmosphere.

10.3.1.5 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit shall be verified.

10.3.1.6 A means shall be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, gas operation may be allowed provided that the gas supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsional vibrations.

10.3.1.7 For engines starting on fuels covered by this Code, if combustion has not been detected by the engine monitoring system within an engine specific time after the opening of the fuel supply valve, the fuel supply valve shall be automatically shut off. Means to ensure that any unburnt fuel mixture is purged away from the exhaust system shall be provided.

10.3.2 Regulations for dual fuel engines

10.3.2.1 In case of shutoff of the gas fuel supply, the engines shall be capable of continuous operation by oil fuel only without interruption.

10.3.2.2 An automatic system shall be fitted to change over from gas fuel operation to oil fuel operation and vice versa with minimum fluctuation of the engine power. Acceptable reliability shall be demonstrated through testing. In the case of unstable operation on engines when gas firing, the engine shall automatically change to oil fuel mode. Manual activation of gas system shutdown shall always be possible.

10.3.2.3 In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

LR 10.3-07 Dual-fuel type engines shall be capable of immediate change-over to oil fuel only. All starting is to be carried out on oil fuel only.

10.3.3 Regulations for gas-only engines

In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

10.3.4 Regulations for multi-fuel engines

10.3.4.1 In case of shutoff of one fuel supply, the engines shall be capable of continuous operation by an alternative fuel with minimum fluctuation of the engine power.

10.3.4.2 An automatic system shall be fitted to change over from one fuel operation to an alternative fuel operation with minimum fluctuation of the engine power. Acceptable reliability shall be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine shall automatically change to an alternative fuel mode. Manual activation shall always be possible.

	GAS ONLY		DUAL FUEL	MULTI FUEL
IGNITION MEDIUM	Spark	Pilot fuel	Pilot fuel	N/A
MAIN FUEL	Gas	Gas	Gas and/ or Oil fuel	Gas and/ or Liquid

10.4 Regulations for main and auxiliary boilers

10.4.1 Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

10.4.2 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.

10.4.3 Burners shall be designed to maintain stable combustion under all firing conditions.

10.4.4 On main/propulsion boilers an automatic system shall be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing.

10.4.5 Gas nozzles and the burner control system shall be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by the Administration to light on gas fuel.

LR 10.4-01 Details of the associated safeguards including processes and procedures are to be submitted where the boiler and combustion equipment is specifically designed for lighting directly on gas fuel.

10.4.6 There shall be arrangements to ensure that gas fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

10.4.7 On the fuel pipe of each gas burner a manually operated shutoff valve shall be fitted.

LR 10.4-02 Each burner supply pipe is to be fitted with a flame arrester unless this is incorporated in the burner.

10.4.8 Provisions shall be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

10.4.9 The automatic fuel changeover system required by 10.4.4 shall be monitored with alarms to ensure continuous availability.

10.4.10 Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

10.4.11 Arrangements shall be made to enable the boilers purging sequence to be manually activated.

LR 10.4-03 In addition to the low water level fuel shut-off and alarm required by *Pt 5, Ch 10.15.7* or *16.7* of the Rules for Ships for oil-fired boilers, equivalent arrangements are to be made for gas shut-off and alarms when the boilers are being gas fired. *See Pt 6, Ch 1* of the Rules for Ships for requirements for control, alarm and safety systems, and additional requirements for unattended operation.

10.5 Regulations for gas turbines

10.5.1 Unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration of explosions due to gas leaks. Pressure relief systems within the exhaust uptakes shall be led to a safe location, away from personnel.

LR 10.5-01 The exhaust system is to be designed to prevent the accumulation of uncombusted gas. Arrangements are to be provided to purge automatically the gas turbine before ignition commences on starting, or recommences after failure to start, or following a loss of ignition in operation. Arrangements are also to be provided to allow manual purging. Interlocking devices are to be fitted to ensure that purging can be carried out only when the fuel supply valves are closed. The purge is to be of sufficient duration and a means of preventing poor combustion which may lead to an accumulation of unburnt gas in the exhaust is to be provided.

10.5.2 The gas turbine may be fitted in a gas-tight enclosure arranged in accordance with the ESD principle outlined in 5.6 and 9.7, however a pressure above 1.0 MPa in the gas supply piping may be accepted within this enclosure.

10.5.3 Gas detection systems and shutdown functions shall be as outlined for ESD protected machinery spaces.

10.5.4 Ventilation for the enclosure shall be as outlined in chapter 13 for ESD protected machinery spaces, but shall in addition be arranged with full redundancy (2 x 100% capacity fans from different electrical circuits).

10.5.5 For other than single fuel gas turbines, an automatic system shall be fitted to change over easily and quickly from gas fuel operation to oil fuel operation and vice-versa with minimum fluctuation of the engine power.

10.5.6 Means shall be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust system during operation. In the event that it is detected, the fuel gas supply shall be shutdown.

10.5.7 Each turbine shall be fitted with an automatic shutdown device for high exhaust temperatures.

11 Fire Safety

11.1 Goal

The goal of this chapter is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of natural gas as ship fuel.

LR 11.1-01 Fire protection, detection and extinction are to be in accordance with the requirements of this Chapter and *Pt 6, Ch 4* of the Rules for Ships.

11.2 Functional requirements

This chapter is related to functional requirements in 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17.

11.3 Regulations for fire protection

11.3.1 Any space containing equipment for the fuel preparation such as pumps, compressors, heat exchangers, vaporizers and pressure vessels shall be regarded as a machinery space of category A for fire protection purposes.

LR 11.3-01 Fire protection in 11.3.1 refers to structural fire protection, not including means of escape.

LR 11.3-02 Enclosed spaces containing equipment for fuel preparation, such as pumps or compressors or other potential ignition sources, are to be provided with a fixed fire-extinguishing system complying with the provisions of SOLAS II-2/10.4.1.1 and the FSS Code, and taking into account the necessary concentrations / application rate required for extinguishing gas fires.

11.3.2 Any boundary of accommodation spaces, service spaces, control stations, escape routes and machinery spaces, facing fuel tanks on open deck, shall be shielded by A-60 class divisions. The A-60 class divisions shall extend up to the underside of the

deck of the navigation bridge. In addition, fuel tanks shall be segregated from cargo in accordance with the requirements of the International Maritime Dangerous Goods (IMDG) Code where the fuel tanks are regarded as bulk packaging. For the purposes of the stowage and segregation requirements of the IMDG Code, a fuel tank on the open deck shall be considered a class 2.1 package.

11.3.3 The space containing fuel containment system shall be separated from the machinery spaces of category A or other rooms with high fire risks. The separation shall be done by a cofferdam of at least 900 mm with insulation of A-60 class. When determining the insulation of the space containing fuel containment system from other spaces with lower fire risks, the fuel containment system shall be considered as a machinery space of category A, in accordance with SOLAS regulation II-2/9. The boundary between spaces containing fuel containment systems shall be either a cofferdam of at least 900 mm or A-60 class division. For type C tanks, the fuel storage hold space may be considered as a cofferdam.

LR 11.3-03 The following ‘other rooms with high fire risk’ shall as a minimum be considered, but not be restricted to:

(a) cargo spaces except cargo tanks for liquids with flashpoint above 60°C and except cargo spaces exempted in accordance with SOLAS regulations II-2/10.7.1.2 or II-2/10.7.1.4;

(b) vehicle, ro-ro and special category spaces;

(c) service spaces (high risk): galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids and workshops other than those forming part of the machinery space, as provided in SOLAS regulations II-2/9.2.2.4, II-2/9.2.3.3 and II-2/9.2.4; and

(d) accommodation spaces of greater fire risk: saunas, sale shops, barber shops and beauty parlours, and public spaces containing furniture and furnishing of other than restricted fire risk and having deck area of 50 m^2 or more, as provided in SOLAS regulation II-2/9.2.2.3.

11.3.4 The fuel storage hold space shall not be used for machinery or equipment that may have a fire risk.

11.3.5 The fire protection of fuel pipes led through ro-ro spaces shall be subject to special consideration by the Administration depending on the use and expected pressure in the pipes.

11.3.6 The bunkering station shall be separated by A-60 class divisions towards machinery spaces of category A, accommodation, control stations and high fire risk spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

LR 11.3-04 For the definitions of sanitary spaces and auxiliary machinery spaces of little or no fire risk, refer to *SOLAS II-2*/9.2.2.3.2.2 (9) and *SOLAS II-2*/9.2.2.3.2.2 (10) respectively.

LR 11.3-05 For the purpose of application of 11.3.3 and 11.3.6, high fire risk areas shall include, but need not be limited to:

(a). spaces assigned fire risk category 11, 12, 13 and 14 as defined in *SOLAS Ch II-2* Reg. 9.2.2.3.2.2;

(b). spaces assigned fire risk category 6, 8, 9 and 11 as defined in *SOLAS Ch II-2* Reg. 9.2.2.4.2.2 and 9.2.3.3.2.2;

(c). spaces assigned fire risk category 6, 8 and 9 as defined in *SOLAS Ch II-2* Reg. 9.2.4.2.2.2; and

(d). special category spaces, vehicle spaces, and ro-ro spaces.

11.3.7 If an ESD protected machinery space is separated by a single boundary, the boundary shall be of A-60 class division.

11.4 Regulations for fire main

11.4.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure are sufficient for the operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.

11.4.2 When the fuel storage tank(s) is located on the open deck, isolating valves shall be fitted in the fire main in order to isolate damaged sections of the fire main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section from the supply of water.

11.5 Regulations for water spray system

11.5.1 A water spray system shall be installed for cooling and fire prevention to cover exposed parts of fuel storage tank(s) located on open deck.

11.5.2 The water spray system shall also provide coverage for boundaries of the superstructures, compressor rooms, pump-rooms, cargo control rooms, bunkering control stations, bunkering stations and any other normally occupied deck houses that face the storage tank on open decks unless the tank is located 10 metres or more from the boundaries.

11.5.3 The system shall be designed to cover all areas as specified above with an application rate of 10 l/min/m^2 for the largest horizontal projected surfaces and 4 l/min/m^2 for vertical surfaces.

11.5.4 Stop valves shall be fitted in the water spray application main supply line(s), at intervals not exceeding 40 metres, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position not likely to be inaccessible in case of fire in the areas protected.

11.5.5 The capacity of the water spray pump shall be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.

11.5.6 If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve shall be provided.

11.5.7 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system shall be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.

11.5.8 The nozzles shall be of an approved full bore type and they shall be arranged to ensure an effective distribution of water throughout the space being protected.

LR 11.5-01 For passenger ships to which the requirements of *SOLAS Ch. II-1/8-1* and *Ch. II-2 Reg. 21* and *22* apply, the water spray system shall remain operational following any casualty as specified in *SOLAS Ch. II-1 Reg. 8-1.2* , *Ch. II-2, Reg. 21.3* and *Reg. 22.3.1*.

11.6 Regulations for dry chemical powder fire-extinguishing system

11.6.1 A permanently installed dry chemical powder fire-extinguishing system shall be installed in the bunkering station area to cover all possible leak points. The capacity shall be at least 3.5 kg/s for a minimum of 45 s. The system shall be arranged for easy manual release from a safe location outside the protected area.

11.6.2 In addition to any other portable fire extinguishers that may be required elsewhere in IMO instruments, one portable dry powder extinguisher of at least 5 kg capacity shall be located near the bunkering station.

11.7 Regulations for fire detection and alarm system

11.7.1 A fixed fire detection and fire alarm system complying with the Fire Safety Systems Code shall be provided for the fuel storage hold spaces and the ventilation trunk to the tank connection space and in the tank connection space, and for all other rooms of the fuel gas system where fire cannot be excluded.

11.7.2 Smoke detectors alone shall not be considered sufficient for rapid detection of a fire.

12 Explosion Prevention

12.1 Goal

The goal of this chapter is to provide for the prevention of explosions and for the limitation of effects from explosion.

12.2 Functional requirements

This chapter is related to functional requirements in 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply:

The probability of explosions shall be reduced to a minimum by:

.1 reducing number of sources of ignition; and

.2 reducing the probability of formation of ignitable mixtures.

12.3 Regulations – General

12.3.1 Hazardous areas on open deck and other spaces not addressed in this chapter shall be decided based on a recognized standard.[19] The electrical equipment fitted within hazardous areas shall be according to the same standard.

[19] Refer to IEC standard 60092-502, part 4.4: Tankers carrying flammable liquefied gases as applicable.

LR 12.3-01 A hazardous areas classification study is to be undertaken. The objective of the study is to identify areas or spaces in which a flammable/explosive atmosphere is present or may be expected to be present, such that potential sources of ignition can be eliminated or controlled, and access to such areas restricted.

LR 12.3-02 The scope of the hazardous areas classification study is to consider all machinery and equipment which could represent a source of release of flammable/explosive gas in:

(a) normal operation, start-up, normal shutdown, non-use, and emergency shutdown of the fuel-gas system;

(b) equipment intended for recovery from unintended releases of gas (e.g. venting systems).

LR 12.3-03 The hazardous areas classification study is to be undertaken:

(a) to identify and categorise areas in which a hazardous atmosphere is present or may occur using International Standard IEC 60079-10-1, Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres or another standard acceptable to LR;

(b) to identify mechanical equipment appropriate for use in a hazardous area using International Standard EN 13463-1, Non-electrical equipment for use in potentially explosive atmospheres or another standard acceptable to LR.

12.3.2 Electrical equipment and wiring shall in general not be installed in hazardous areas unless essential for operational purposes based on a recognized standard.[20]

LR 12.3-04 Electrical equipment and components intended for use in hazardous areas are to be of a certified type in accordance with *Pt 6, Ch 2,14* of the Rules for Ships or an acceptable and relevant National Standard.

LR 12.3-05 Mechanical equipment and components intended for use in a hazardous area are to be designed, constructed and installed to ensure that they are:

(a) suitable for operation in normal or foreseeable hazardous conditions;

(b) suitable for operation in a hazardous atmosphere that may be produced or released by the components or equipment; and

(c) suitable for operation in hazardous atmospheres, taking into account the nature of every electrical and non-electrical source of ignition.

LR 12.3-06 Equipment which may produce hot particles or hot surfaces and which is intended to be located less than 3,5 m above a hazardous area is to be either totally enclosed or provided with suitable guards or screens to prevent ignition sources falling into the hazardous area.

LR 12.3-07 Low-pressure sodium vapour discharge lamps are not to be installed above a hazardous area.

LR 12.3-08 Where insulating materials are used to protect against the effects of high surface temperatures, they are to prevent the ingress of gas.

12.3.3 Electrical equipment fitted in an ESD-protected machinery space shall fulfil the following:

.1 in addition to fire and gas hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans shall be certified safe for hazardous area zone 1; and

.2 all electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 shall be automatically disconnected, if gas concentration above 40% LEL is detected by two detectors in the space containing gas-fuelled consumers.

12.4 Regulations on area classification

12.4.1 Area classification is a method of analysing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

12.4.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2.[21] See also 12.5 below.

[20] Refer to IEC standard 60092-502: IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features and IEC 60079-10-1:2008 Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres, according to the area classification.

[21] Refer to standards IEC 60079-10-1:2008 Explosive atmospheres part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special Features for tankers.

LR 12.4-01 The requirements of 12.4.2 are also to be applied for the selection of appropriate mechanical equipment and the design of mechanical installations.

12.4.3 Ventilation ducts shall have the same area classification as the ventilated space.

12.5 Hazardous area zones

LR 12.5-01 The hazardous areas identified in 12.5.2 and 12.5.3 are only valid for the following assumptions. If either (a) or (b) is not met, hazardous areas are to be determined in accordance with *LR 12.3-03*:

(a) ventilation is supplied: at least 30 air changes per hour;

(b) gas supply pressure does not exceed 10 bar.

12.5.1 Hazardous area zone 0

This zone includes, but is not limited to the interiors of fuel tanks, any pipework for pressure-relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

12.5.2 Hazardous area zone 1[22]

This zone includes, but is not limited to:

.1 tank connection spaces, fuel storage hold spaces[23] and interbarrier spaces;

LR 12.5-02 For the purposes of hazardous area classification, fuel storage hold spaces containing Type C tanks with all potential leakage sources in a tank connection space and having no access to any hazardous area, shall be considered non-hazardous.

LR 12.5-03 Where the fuel storage hold spaces include potential leak sources, e.g. tank connections, they shall be considered hazardous area zone 1.

LR 12.5-04 Where the fuel storage hold spaces include bolted access to the tank connection space, they shall be considered hazardous area zone 2.

.2 fuel preparation room arranged with ventilation according to 13.6;

.3 areas on open deck, or semi-enclosed spaces on deck, within 3 m of any fuel tank outlet,[24] gas or vapour outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets and fuel tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces;

.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

.6 enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts around fuel pipes, semi-enclosed bunkering stations;

.7 the ESD-protected machinery space is considered a non-hazardous area during normal operation, but will require equipment required to operate following detection of gas leakage to be certified as suitable for zone 1;

.8 a space protected by an airlock is considered as non-hazardous area during normal operation, but will require equipment required to operate following loss of differential pressure between the protected space and the hazardous area to be certified as suitable for zone 1; and

22 Instrumentation and electrical apparatus installed within these areas should be of a type suitable for zone 1.
23 Fuel storage hold spaces for type C tanks are normally not considered as zone 1.
24 Such areas are, for example, all areas within 3 m of fuel tank hatches, ullage openings or sounding pipes for fuel tanks located on open deck and gas vapour outlets.

.9 except for type C tanks, an area within 2.4 m of the outer surface of a fuel containment system where such surface is exposed to the weather.

LR 12.5-05 In addition to the areas defined in 12.5.2, hazardous area zone 1 also includes:

(a) enclosures or compartments containing gas regulating and block and bleed valves;

(b) areas on open deck or semi-enclosed spaces on deck, within 3 m of ventilation outlets of spaces identified in 12.5.2.1 and 12.5.2.6 and LR 12.5-02 (a);

(c) areas on open deck or semi-enclosed spaces on deck within the vicinity of any gas tank outlet intended for the passage of large volumes of gas or vapour (e.g. fuel containment pressure relief valves); this hazardous area is defined as a vertical cylinder clear of obstructions and 6 m radius centred upon the centre of the outlet and within a hemisphere of 6 m radius below the outlet.

12.5.3 Hazardous area zone 2[25]

12.5.3.1 This zone includes, but is not limited to areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

12.5.3.2 Space containing bolted hatch to tank connection space.

LR 12.5-06 In agreement with the National Administration, time restricted access to the tank connection space via a bolted hatch in a non-hazardous space may be considered in accordance with EN 60079 (A2.2 Opening classification).

LR 12.5-07 In addition to the areas defined in 12.5.3.1 and 12.5.3.2, hazardous area zone 2 also includes:

(a) areas 4 m beyond the cylinder and 4 m beyond the sphere defined in LR 12.5-02 (c);

(b) areas 3 m beyond the areas in 12.5.2.4 up to a height of 2,4 m above the deck;

(c) air-locks protecting a non-hazardous area from a zone 1 area.

LR 12.5-08 Hazardous areas associated with the use of integral structural fuel containment systems are to be specially considered.

LR 12.5-09 Hazardous area classification of the fuel storage hold space is to be specially considered with regard to the access arrangements to the tank connection space and the presence of any equipment and openings which could present a source of gas release.

13 Ventilation

13.1 Goal

The goal of this chapter is to provide for the ventilation required for safe operation of gas-fuelled machinery and equipment.

13.2 Functional requirements

This chapter is related to functional requirements in 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

13.3 Regulations – General

13.3.1 Any ducting used for the ventilation of hazardous spaces shall be separate from that used for the ventilation of non-hazardous spaces. The ventilation shall function at all temperatures and environmental conditions the ship will be operating in.

13.3.2 Electric motors for ventilation fans shall not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.

13.3.3 Design of ventilation fans serving spaces containing gas sources shall fulfil the following:

.1 Ventilation fans shall not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, shall be of non-sparking construction defined as:

.1 impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

.2 impellers and housings of non-ferrous metals;

.3 impellers and housings of austenitic stainless steel;

[25] Instrumentation and electrical apparatus installed within these areas should be of a type suitable for zone 2.

.4 impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

.5 any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

.2 In no case shall the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

.3 Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in these places.

13.3.4 Ventilation systems required to avoid any gas accumulation shall consist of independent fans, each of sufficient capacity, unless otherwise specified in this Code.

13.3.5 Air inlets for hazardous enclosed spaces shall be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces shall be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct shall be gas-tight and have over-pressure relative to this space.

13.3.6 Air outlets from non-hazardous spaces shall be located outside hazardous areas.

13.3.7 Air outlets from hazardous enclosed spaces shall be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

13.3.8 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

13.3.9 Non-hazardous spaces with entry openings to a hazardous area shall be arranged with an airlock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation shall be arranged according to the following:

.1 During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it shall be required to:

.1 proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and

.2 pressurize the space.

.2 Operation of the overpressure ventilation shall be monitored and in the event of failure of the overpressure ventilation:

.1 an audible and visual alarm shall be given at a manned location; and

.2 if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard[26] shall be required.

13.3.10 Non-hazardous spaces with entry openings to a hazardous enclosed space shall be arranged with an airlock and the hazardous space shall be maintained at underpressure relative to the non-hazardous space. Operation of the extraction ventilation in the hazardous space shall be monitored and in the event of failure of the extraction ventilation:

.1 an audible and visual alarm shall be given at a manned location; and

.2 if underpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard in the non-hazardous space shall be required.

LR 13.3-01 All spaces that are adjacent to more hazardous spaces or areas, are to be maintained at a pressure 25 Pa (0,25 mbar) or more above the pressure of the more hazardous space or area.

LR 13.3-02 In general, ventilators necessary to continuously supply the machinery space are to have coamings of sufficient height as described in *Pt 3, Ch 12,2.4.1* of the Rules for Ships.

13.4 Regulations for tank connection space

13.4.1 The tank connection space shall be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour shall be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations shall be demonstrated by a risk assessment.

13.4.2 Approved automatic fail-safe fire dampers shall be fitted in the ventilation trunk for the tank connection space.

[26] Refer to IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features, table 5.

LR 13.4-01 It is to be confirmed if 'fail-safe' is 'fail-close' or 'fail-open' and agreed with LR.

LR 13.4-02 In lieu of an automatic fail–safe fire damper, other arrangements providing an equivalent level of safety will be considered subject to agreement by the National Administration.

13.5 Regulations for machinery spaces

13.5.1 The ventilation system for machinery spaces containing gas-fuelled consumers shall be independent of all other ventilation systems.

LR 13.5-01 Spaces enclosed within the boundaries of machinery spaces (such as purifier rooms, engine-room workshops and stores) are considered an integral part of machinery spaces containing gas-fuelled consumers and, therefore, their ventilation system does not need to be independent of the ventilation system serving the machinery spaces.

13.5.2 ESD protected machinery spaces shall have ventilation with a capacity of at least 30 air changes per hour. The ventilation system shall ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby under normal operation the machinery spaces are ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.

13.5.3 For ESD protected machinery spaces the ventilation arrangements shall provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard acceptable to the Organization.[27]

13.5.4 The number and power of the ventilation fans for ESD protected engine-rooms and for double pipe ventilation systems for gas safe engine-rooms shall be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

13.6 Regulations for fuel preparation room

13.6.1 Fuel preparation rooms, shall be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour.

13.6.2 The number and power of the ventilation fans shall be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

13.6.3 Ventilation systems for fuel preparation rooms, shall be in operation when pumps or compressors are working.

13.7 Regulations for bunkering station

Bunkering stations that are not located on open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment required by 8.3.1.1.

13.8 Regulations for ducts and double pipes

13.8.1 Ducts and double pipes containing fuel piping shall be fitted with effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour. This is not applicable to double pipes in the engine-room if fulfilling 9.6.1.1.

13.8.2 The ventilation system for double piping and for gas valve unit spaces in gas safe engine-rooms shall be independent of all other ventilation systems.

LR 13.8-01 The ventilation system for double piping and gas valve unit spaces in gas safe engine-rooms may extend outside of the gas safe engine-rooms.

13.8.3 The ventilation inlet for the double wall piping or duct shall always be located in a non-hazardous area away from ignition sources. The inlet opening shall be fitted with a suitable wire mesh guard and protected from ingress of water.

LR 13.8-02 The ventilation inlet referred to in 13.8.3 shall always be located in open air.

[27] Refer to IEC 60079-10-1.

13.8.4 The capacity of the ventilation for a pipe duct or double wall piping may be below 30 air changes per hour if a flow velocity of minimum 3 m/s is ensured. The flow velocity shall be calculated for the duct with fuel pipes and other components installed.

14 Electrical Installations

14.1 Goal

The goal of this chapter is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.

14.2 Functional requirements

This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following apply:

Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressures and hull structure temperature within normal operating limits.

14.3 Regulations – General

LR 14.3-01 The electrical installation is to be designed, constructed and installed in accordance with the requirements of *Pt 6, Ch 2* of the Rules for Ships.

14.3.1 Electrical installations shall be in compliance with a standard at least equivalent to those acceptable to the Organization.[28]

14.3.2 Electrical equipment or wiring shall not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

14.3.3 Where electrical equipment is installed in hazardous areas as provided in 14.3.2 it shall be selected, installed and maintained in accordance with standards at least equivalent to those acceptable to the Organization.[29]

Equipment for hazardous areas shall be evaluated and certified or listed by an accredited testing authority or notified body recognized by the Administration.

14.3.4 Failure modes and effects of single failure for electrical generation and distribution systems in 14.2 shall be analysed and documented to be at least equivalent to those acceptable to the Organization.[30]

14.3.5 The lighting system in hazardous areas shall be divided between at least two branch circuits. All switches and protective devices shall interrupt all poles or phases and shall be located in a non-hazardous area.

14.3.6 The installation on board of the electrical equipment units shall be such as to ensure the safe bonding to the hull of the units themselves.

14.3.7 Arrangements shall be made to alarm in low-low liquid level and automatically shutdown the motors in the event of low-low liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

14.3.8 Submerged fuel pump motors and their supply cables may be fitted in liquefied gas fuel containment systems. Fuel pump motors shall be capable of being isolated from their electrical supply during gas-freeing operations.

14.3.9 For non-hazardous spaces with access from hazardous open deck where the access is protected by an airlock, electrical equipment which is not of the certified safe type shall be de-energized upon loss of overpressure in the space.

14.3.10 Electrical equipment for propulsion, power generation, manoeuvring, anchoring and mooring, as well as emergency fire pumps, that are located in spaces protected by airlocks, shall be of a certified safe type.

[28] Refer to IEC 60092 series standards, as applicable.
[29] Refer to the recommendation published by the International Electrotechnical Commission, in particular to publication IEC 60092-502:1999.
[30] Refer to IEC 60812.

15 Control, Monitoring and Safety Systems

15.1 Goal

The goal of this chapter is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fuelled installation as covered in the other chapters of this Code.

15.2 Functional requirements

This chapter is related to functional requirements in 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18. In particular the following apply:

.1 the control, monitoring and safety systems of the gas-fuelled installation shall be so arranged that the remaining power for propulsion and power generation is in accordance with 9.3.1 in the event of single failure;

.2 a gas safety system shall be arranged to close down the gas supply system automatically, upon failure in systems as described in table 1 and upon other fault conditions which may develop too fast for manual intervention;

.3 for ESD protected machinery configurations the safety system shall shutdown gas supply upon gas leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

.4 the safety functions shall be arranged in a dedicated gas safety system that is independent of the gas control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

.5 the safety systems including the field instrumentation shall be arranged to avoid spurious shutdown, e.g. as a result of a faulty gas detector or a wire break in a sensor loop; and

.6 where two or more gas supply systems are required to meet the regulations, each system shall be fitted with its own set of independent gas control and gas safety systems.

LR 15.2-01 The gas safety system is to be designed to ‘fail-safe’ such that failure does not result in a hazardous situation. The behaviour and status on failure and fault detection are to be defined.

LR 15.2-02 The gas safety system and gas fuel control system shall be provided with:

(a) fault tolerance of sensor inputs, e.g. range checking, wire breaking monitoring;

(b) self-monitoring capabilities to detect both functional and hardware failures;

(c) proportional control valves with position feedback;

(d) manual control of remotely controlled equipment (where appropriate);

(e) instrumentation devices to allow local and remote reading of essential parameters associated with storage, processing and bunkering;

(f) redundant data communication (where redundancy is required); and

(g) safeguards to prevent unauthorised modification of process-related parameters.

15.3 Regulations – General

LR 15.3-01 Control, alert and safety systems are to comply with the relevant requirements of *Pt 5* and *Pt 6, Ch 1* of the Rules for Ships.

15.3.1 Suitable instrumentation devices shall be fitted to allow a local and a remote reading of essential parameters to ensure a safe management of the whole fuel-gas equipment including bunkering.

LR 15.3-02 Arrangements are to be made so that the gas supply to the gas-fuelled machinery and equipment can be shut off manually from any space or area containing gas-fuelled machinery and equipment, the engine starting platform or any other control position.

15.3.2 A bilge well in each tank connection space of an independent liquefied gas storage tank shall be provided with both a level indicator and a temperature sensor. Alarm shall be given at high level in the bilge well. Low temperature indication shall activate the safety system.

LR 15.3-03 The level indicator is required for the purposes of indicating an alarm status only; a level switch (float switch) is an instrument, for example, considered to meet this requirement.

15.3.3 For tanks not permanently installed in the ship a monitoring system shall be provided as for permanently installed tanks.

15.4 Regulations for bunkering and liquefied gas fuel tank monitoring

LR 15.4-01 As a minimum, each tank is to be provided with the following monitoring:

(a) Vapour space pressure. Pressure indicators are to be clearly marked with the highest and lowest pressure permitted in the tank. The high pressure alarms are to be activated before the set pressures of the pressure relief valves;

(b) Vapour space temperature;

(c) Liquid level.

15.4.1 Level indicators for liquefied gas fuel tanks

.1 Each liquefied gas fuel tank shall be fitted with liquid level gauging device(s), arranged to ensure a level reading is always obtainable whenever the liquefied gas fuel tank is operational. The device(s) shall be designed to operate throughout the design pressure range of the liquefied gas fuel tank and at temperatures within the fuel operating temperature range.

.2 Where only one liquid level gauge is fitted it shall be arranged so that it can be maintained in an operational condition without the need to empty or gas-free the tank.

.3 Liquefied gas fuel tank liquid level gauges may be of the following types:

.1 indirect devices, which determine the amount of fuel by means such as weighing or in-line flow metering; or

.2 closed devices, which do not penetrate the liquefied gas fuel tank, such as devices using radio-isotopes or ultrasonic devices;

15.4.2 Overflow control

.1 Each liquefied gas fuel tank shall be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated.

.2 An additional sensor operating independently of the high liquid level alarm shall automatically actuate a shutoff valve in a manner that will both avoid excessive liquid pressure in the bunkering line and prevent the liquefied gas fuel tank from becoming liquid full.

.3 The position of the sensors in the liquefied gas fuel tank shall be capable of being verified before commissioning. At the first occasion of full loading after delivery and after each dry-docking, testing of high level alarms shall be conducted by raising the fuel liquid level in the liquefied gas fuel tank to the alarm point.

LR 15.4-02 The expression ‘each dry-docking’ refers to:

(a) for cargo ships, the survey of the outside of the ship's bottom required for the renewal of the Cargo Ship Safety Construction Certificate and/or the Cargo Ship Safety Certificate; and

(b) for passenger ships, the survey of the outside of the ship's bottom to be carried out according to paragraphs 5.10.1 and 5.10.2 of the Survey Guidelines under the Harmonized System of Survey and Certification.

.4 All elements of the level alarms, including the electrical circuit and the sensor(s), of the high, and overfill alarms, shall be capable of being functionally tested. Systems shall be tested prior to fuel operation in accordance with 18.4.3.

.5 Where arrangements are provided for overriding the overflow control system, they shall be such that inadvertent operation is prevented. When this override is operated continuous visual indication is to be provided at the navigation bridge, continuously manned central control station or onboard safety centre.

15.4.3 The vapour space of each liquefied gas fuel tank shall be provided with a direct reading gauge. Additionally, an indirect indication is to be provided on the navigation bridge, continuously manned central control station or onboard safety centre.

LR 15.4-03 These reading gauge(s) are to be provided for both pressure and temperature measurement and are to be located in the tank connection space or a space meeting the requirements for a tank connection space, close to the storage tank.

15.4.4 The pressure indicators shall be clearly marked with the highest and lowest pressure permitted in the liquefied gas fuel tank.

15.4.5 A high-pressure alarm and, if vacuum protection is required, a low-pressure alarm shall be provided on the navigation bridge and at a continuously manned central control station or onboard safety centre. Alarms shall be activated before the set pressures of the safety valves are reached.

15.4.6 Each fuel pump discharge line and each liquid and vapour fuel manifold shall be provided with at least one local pressure indicator.

15.4.7 Local-reading manifold pressure indicator shall be provided to indicate the pressure between ship's manifold valves and hose connections to the shore.

15.4.8 Fuel storage hold spaces and interbarrier spaces without open connection to the atmosphere shall be provided with pressure indicator.

15.4.9 At least one of the pressure indicators provided shall be capable of indicating throughout the operating pressure range.

15.4.10 For submerged fuel-pump motors and their supply cables, arrangements shall be made to alarm in low-liquid level and automatically shutdown the motors in the event of low-low liquid level. The automatic shutdown may be accomplished by sensing low pump discharge pressure, low motor current, or low-liquid level. This shutdown shall give an audible and visual alarm on the navigation bridge, continuously manned central control station or onboard safety centre.

15.4.11 Except for independent tanks of type C supplied with vacuum insulation system and pressure build-up fuel discharge unit, each fuel tank shall be provided with devices to measure and indicate the temperature of the fuel in at least three locations; at the bottom and middle of the tank as well as the top of the tank below the highest allowable liquid level.

15.5 Regulations for bunkering control

15.5.1 Control of the bunkering shall be possible from a safe location remote from the bunkering station. At this location the tank pressure, tank temperature if required by 15.4.11, and tank level shall be monitored. Remotely controlled valves required by 8.5.3 and 11.5.7 shall be capable of being operated from this location. Overfill alarm and automatic shutdown shall also be indicated at this location.

LR 15.5-01 A method of providing communication with the bunker supply system is to be provided. Where practicable, this system is to be of a linked type system and is to connect to the ship’s gas safety system, *see* 8.5.7.

15.5.2 If the ventilation in the ducting enclosing the bunkering lines stops, an audible and visual alarm shall be provided at the bunkering control location, see also 15.8.

15.5.3 If gas is detected in the ducting around the bunkering lines an audible and visual alarm and emergency shutdown shall be provided at the bunkering control location.

15.6 Regulations for gas compressor monitoring

15.6.1 Gas compressors shall be fitted with audible and visual alarms both on the navigation bridge and in the engine control room. As a minimum the alarms shall include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

15.6.2 Temperature monitoring for the bulkhead shaft glands and bearings shall be provided, which automatically give a continuous audible and visual alarm on the navigation bridge or in a continuously manned central control station.

15.7 Regulations for gas engine monitoring

In addition to the instrumentation provided in accordance with part C of SOLAS chapter II-1, indicators shall be fitted on the navigation bridge, the engine control room and the manoeuvring platform for:

.1 operation of the engine in case of gas-only engines; or

.2 operation and mode of operation of the engine in the case of dual fuel engines.

LR 15.7-01 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions that could introduce an unsafe situation.

15.8 Regulations for gas detection

15.8.1 Permanently installed gas detectors shall be fitted in:

.1 the tank connection spaces;

.2 all ducts around fuel pipes;

.3 machinery spaces containing gas piping, gas equipment or gas consumers;

.4 compressor rooms and fuel preparation rooms;

.5 other enclosed spaces containing fuel piping or other fuel equipment without ducting;

.6 other enclosed or semi-enclosed spaces where fuel vapours may accumulate including interbarrier spaces and fuel storage hold spaces of independent tanks other than type C;

.7 airlocks;

.8 gas heating circuit expansion tanks;

.9 motor rooms associated with the fuel systems; and

.10 at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in 4.2.

LR 15.8-01 In addition to the areas identified in 15.8.1, the following areas are also to be fitted with gas detection:

(a) any spaces requiring gas detection as identified as part of RBD and the safety concept for gas-fuelled machinery;

(b) vent outlet from lubricating oil purifiers;

(c) vent outlet from engine cooling water expansion tank.

15.8.2 In each ESD-protected machinery space, redundant gas detection systems shall be provided.

15.8.3 The number of detectors in each space shall be considered taking into account the size, layout and ventilation of the space.

15.8.4 The detection equipment shall be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis or a physical smoke test shall be used to find the best arrangement.

LR 15.8-02 The detector or sampling heads of the fuel gas detection systems are not to be located where liquid can collect. Pipe runs from sampling heads are not to be led through non-hazardous spaces, except as permitted by LR 15.8-09.

15.8.5 Gas detection equipment shall be designed, installed and tested in accordance with a recognized standard.[31]

LR 15.8-03 In addition, the equipment is to be designed to be self-monitoring such that failure of the control panel, detector heads or sampling unit can be detected and an audible and visual alarm provided.

LR 15.8-04 Gas detection equipment is to be designed so that it may be readily tested. Testing and calibration is to be capable of being carried out at regular intervals. Arrangements are to be made for suitable equipment and span gas for testing and calibration purposes to be carried on board. Wherever practicable, provision is to be made for permanent connections for attachment of testing and calibration equipment.

LR 15.8-05 In the selection of detectors for locations identified in 15.8.1.8 and *LR 15.8-01* due consideration is to be taken of temperature and humidity of the environment in which gas is being detected. For sampling systems, the system is to include a method to dry and cool the sampled environment to that in which gas can be accurately detected.

15.8.6 An audible and visible alarm shall be activated at a gas vapour concentration of 20% of the lower explosion limit (LEL). The safety system shall be activated at 40% of LEL at two detectors (see footnote 1 in table 1).

15.8.7 For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% LEL. The safety system shall be activated at 60% of LEL at two detectors (see footnote 1 in table 1).

15.8.8 Audible and visible alarms from the gas detection equipment shall be located on the navigation bridge or in the continuously manned central control station.

15.8.9 Gas detection required by this section shall be continuous without delay.

LR 15.8-06 Where gas detection not used to activate safety shutdown functions required by these Rules, sampling type detection may be accepted in agreement with the National Administration.

LR 15.8-07 When sampling type gas detection equipment is used, the following requirements are to be met:

(a) the gas detection equipment is to be capable of sampling and analysing for each sampling head location sequentially at intervals which are as short as possible but do not exceed 30 minutes;

(b) individual sampling lines from sampling heads to the detection equipment are to be fitted; and

[31] Refer to IEC 60079-29-1 – Explosive atmospheres – Gas detectors – Performance requirements of detectors for flammable detectors.

(c) pipe runs from sampling heads are not to be led through non-hazardous spaces, except as permitted by LR 15.8-09.

LR 15.8-08 Sampling type gas detection equipment may be located in a non-hazardous space, provided that the detection equipment such as sample piping, sample pumps, solenoids and analysing units are located in a fully enclosed steel cabinet with the door sealed by a gasket. The atmosphere within the enclosure is to be continuously monitored. At gas concentrations above 30 per cent LEL inside the enclosure, the entire gas detection unit is to be automatically shut down including all power to external equipment.

LR 15.8-09 Additionally, where sampling type gas detection equipment is located in a non-hazardous space, the following conditions are also to be satisfied:

(a) fuel gas sampling lines are to have shut-off valves or an equivalent arrangement to prevent cross communication with hazardous spaces; and

(b) exhaust gas from the detector is to be discharged to the atmosphere in a safe location.

15.9 Regulations for fire detection

Required safety actions at fire detection in the machinery space containing gas-fuelled engines and rooms containing independent tanks for fuel storage hold spaces are given in table 1 below.

LR 15.9-01 A fire detection and alarm system, satisfying the requirements of *Pt 6, Ch 1,2.8* of the Rules for Ships, is to be fitted in all spaces containing potential sources of gas leakage and ignition.

LR 15.9-02 Fire detection is to be arranged such that the activation of any fire detectors in hazardous areas, spaces containing gas-fuelled equipment, spaces adjacent to hazardous areas or gas-fuelled equipment, automatically shuts down the gas supply system.

15.10 Regulations for ventilation

15.10.1 Any loss of the required ventilating capacity shall give an audible and visual alarm on the navigation bridge or in a continuously manned central control station or safety centre.

LR 15.10-01 Acceptable means to confirm that the ventilation system has the required ventilating capacity in operation are, but not limited to:

a) Monitoring of the ventilation electric motor or fan operation combined with underpressure indication; or
b) Monitoring of the ventilation electric motor or fan operation combined with ventilation flow indication; or
c) Monitoring of ventilation flow rate to indicate that the required air flow rate is established.

15.10.2 For ESD protected machinery spaces the safety system shall be activated upon loss of ventilation in engine-room.

15.11 Regulations on safety functions of fuel supply systems

15.11.1 If the fuel supply is shut off due to activation of an automatic valve, the fuel supply shall not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect shall be placed at the operating station for the shutoff valves in the fuel supply lines.

15.11.2 If a fuel leak leading to a fuel supply shutdown occurs, the fuel supply shall not be operated until the leak has been found and dealt with. Instructions to this effect shall be placed in a prominent position in the machinery space.

15.11.3 A caution placard or signboard shall be permanently fitted in the machinery space containing gas-fuelled engines stating that heavy lifting, implying danger of damage to the fuel pipes, shall not be done when the engine(s) is running on gas.

15.11.4 Compressors, pumps and fuel supply shall be arranged for manual remote emergency stop from the following locations as applicable:

.1 navigation bridge;
.2 cargo control room;
.3 onboard safety centre;
.4 engine control room;
.5 fire control station; and
.6 adjacent to the exit of fuel preparation rooms.

The gas compressor shall also be arranged for manual local emergency stop.

Table 1: Monitoring of gas supply system to engines

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Gas detection in tank connection space at 20% LEL	X			
Gas detection on two detectors[1)] in tank connection space at 40% LEL	X	X		
Fire detection in fuel storage hold space	X			
Fire detection in ventilation trunk to the tank connection space and in the tank connection space	X			
Bilge well high level in tank connection space	X			
Bilge well low temperature in tank connection space	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL	X			
Gas detection on two detectors[1)] in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	X	X[2)]		
Gas detection in fuel preparation room at 20% LEL	X			
Gas detection on two detectors[1)] in fuel preparation room at 40% LEL	X	X[2)]		
Gas detection in duct inside machinery space containing gas-fuelled engines at 30% LEL	X			If double pipe fitted in machinery space containing gas-fuelled engines

Gas detection on two detectors[1)] in duct inside machinery space containing gas-fuelled engines at 60% LEL	X		X[3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	X			
Gas detection on two detectors[1)] in ESD protected machinery space containing gas-fuelled engines at 40% LEL	X		X	It shall also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	X		X[2)]	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines[5)]	X		X[3)]	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	X		X	
Fire detection in machinery space containing gas-fuelled engines	X			
Abnormal gas pressure in gas supply pipe	X			
Failure of valve control actuating medium	X		X[4)]	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X[4)]	
Manually activated emergency shutdown of engine	X		X	

1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted.

2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected shall close.

3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected shall close.

4) Only double block and bleed valves to close.
5) If the duct is protected by inert gas (see 9.6.1.1) then loss of inert gas overpressure shall lead to the same actions as given in this table.
6) Valves referred to in 9.4.1.

LR Table 1: Monitoring of gas supply system to engines

Parameter	Alarm	Automatic shutdown of tank valve[6)]	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comments
Gas detection in tank connection space at 20% LEL	X			
Gas detection on two detectors[1)] in tank connection space at 40% LEL	X	X		
Fire detection in fuel storage hold space	X			(*See* LR 1-3 & 5)
Fire detection in ventilation trunk for fuel containment system below deck	X			(*See* LR 1-3 & 5)
Bilge well high level in tank connection space	X			
Bilge well low temperature in tank connection space	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines at 20% LEL	X			
Gas detection on two detectors[1)] in duct between tank and machinery space containing gas-fuelled engines at 40% LEL	X	X[2)]		
Gas detection in fuel preparation room at 20% LEL	X			
Gas detection on two detectors[1)] in fuel preparation room at 40% LEL	X	X[2)]		

Gas detection in duct inside machinery space containing gas-fuelled engines at 30% LEL	X			If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors1) in duct inside machinery space containing gas-fuelled engines at 60% LEL	X		X3)	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in ESD protected machinery space containing gas-fuelled engines at 20% LEL	X			
Gas detection on two detectors1) in ESD protected machinery space containing gas-fuelled engines at 40% LEL	X		X	It shall also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery space containing gas-fuelled engines	X		X2)	(*See* LR 1-3)
Loss of ventilation in duct inside machinery space containing gas-fuelled engines5)	X		X3)	If double pipe fitted in machinery space containing gas-fuelled engines (*See* LR 1-3 & 6)
Loss of ventilation in ESD protected machinery space containing gas-fuelled engines	X		X	
Fire detection in machinery space containing gas-fuelled engines	X			(*See* LR 1-3 & 5)
Abnormal gas pressure in gas supply pipe	X			(*See* LR 1-3)
Failure of valve control actuating medium	X		X4)	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	X		X4)	
Manually activated emergency shutdown of engine	X		X	
1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self-monitoring type the installation of a single gas detector can be permitted.				

2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected shall close.
3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected shall close.
4) Only double block and bleed valves to close.
5) If the duct is protected by inert gas (see 9.6.1.1) then loss of inert gas overpressure shall lead to the same actions as given in this table.
6) Valves referred to in 9.4.1.
NOTES
LR 1 Gas fuel supply shutdown by automatic operation of gas supply line double block-and-bleed valves.
LR 2 Alarms associated with gas fuel supply and ventilation arrangements are to be given in the machinery space and machinery control station.
LR 3 *See* 10.3.4 for alternative gas fuel supply requirements.
LR 4 High temperature alarm to operate at all times when tank is in operation.
LR 5 Fire detection in spaces containing gas-fuelled equipment or in adjacent spaces to result in gas fuel supply shutdown.
LR 6 Actual valve position is to be positively indicated at the required remote control position.
LR 7 Arrangements are to prevent automatic or remote starting under conditions which could cause a hazardous situation.

LR 15.11-01 Any additional alarms and shutdowns determined on the basis of RBD are to be provided as necessary.

LR 15.11-02

Table 1.15.1 Gas fuel supply and storage: Alarms, monitoring and safeguards

Item	Alarm	Note
Gas fuel storage tanks	High level, high temperature	Gas fuel bunkering alarms are to be given in the bunkering control station, (*See* LR 4)
Gas fuel storage tanks	High pressure, high-high level, overfill, low pressure (if vacuum insulated tank)	Gas fuel bunkering shutdown
Bunkering	Bunker line high pressure, loss of communication	Gas fuel bunkering shutdown
Fire	Fire detection	Gasfuel supply shutdown. (*See* LR 1-3 & 5)
Space ventilation system	Failure	
NOTES		
LR 1 Gas fuel supply shutdown by automatic operation of gas supply line double block-and-bleed valves.		
LR 2 Alarms associated with gas fuel supply and ventilation arrangements are to be given in the machinery space and machinery control station.		
LR 3 *See* 10.3.4 for alternative gas fuel supply requirements.		
LR 4 High temperature alarm to operate at all times when tank is in operation.		
LR 5 Fire detection in spaces containing gas-fuelled equipment or in adjacent spaces to result in gas fuel supply shutdown.		
LR 6 Actual valve position is to be positively indicated at the required remote control position.		
LR 7 Arrangements are to prevent automatic or remote starting under conditions which could cause a hazardous situation.		

LR 8 Alarm is to be given at the gas fuel bunkering control station. LR 9 For high pressure alarm, *see* 6.3.2.

LR 15.11-03

Table 1.15.2 Gas-fuelled machinery: Alarms, monitoring and safeguards

Item	Alarm	Note
Engine crankcase protection	High oil mist concentration, see (*See* LR 1)	*See* safety concept, LR 10.3-03 *See* 15.8.5 for gas detection equipment requirements as applicable
Engine gas supply pressure	Low	Automatic closing of gas supply manifold isolating valve *See* 10.3.4 foralternative gas fuel supply requirements
Engine gas fuel injection	Cylinder misfire Gas fuel or pilot fuel injection valve failure	(*See* LR 3)
Exhaust gas temperature	High	Per cylinder, (*See* LR 3)
Exhaust gas temperature deviation from average	High	Per cylinder, (*See* LR 3)
Cylinder pressure	Low	Alternatively, ignition failure monitoring and alarms of each cylinder are permitted, (*See* LR 3)
Engine shutdown		Automatic closing of gas supply manifold isolating valve
Burner flame and ignition	Failure	Each burner to be monitored, (*See* LR 5)
Boiler shutdown		(*See* LR 4 & 5)
Fuel injection valve cooling water pressure	Low	
Fuel injection valve cooling water temperature	High	
NOTES LR 1 Bearing temperature monitoring is permitted in lieu of oil mist monitoring for dual fuel crosshead type engines. LR 2 Alarm set point to allow sufficient time for corrective action necessary to avoid increased risk of explosion. Alarm set point not to exceed LEL. LR 3 Automatic operation of gas supply line double block-and-bleed valves and closing of supply line master gas fuel valve. LR 4 Automatic operation of gas supply line double block-and-bleed valves. LR 5 Combustion spaces are to be purged automatically before re-ignition takes place in the event of flame-out on all burners. LR 6 Machinery alarms are to be given in the machinery space and the machinery control station, in accordance with Pt 6, Ch 1,2.3.1 of the Rules for Ships.		

Annex - Standard for the Use of Limit State Methodologies in the Design of Fuel Containment Systems of Novel Configuration

1 General

1.1 The purpose of this standard is to provide procedures and relevant design parameters of limit state design of fuel containment systems of a novel configuration in accordance with section 6.4.16.

1.2 Limit state design is a systematic approach where each structural element is evaluated with respect to possible failure modes related to the design conditions identified in 6.4.1.6. A limit state can be defined as a condition beyond which the structure, or part of a structure, no longer satisfies the regulations.

1.3 The limit states are divided into the three following categories:

.1 Ultimate Limit States (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain, deformation or instability in structure resulting from buckling and plastic collapse; under intact (undamaged) conditions;

.2 Fatigue Limit States (FLS), which correspond to degradation due to the effect of cyclic loading; and

.3 Accident Limit States (ALS), which concern the ability of the structure to resist accident situations.

1.4 Section 6.4.1 through to section 6.4.14 shall be complied with as applicable depending on the fuel containment system concept.

2 Design Format

2.1 The design format in this standard is based on a Load and Resistance Factor Design format. The fundamental principle of the Load and Resistance Factor Design format is to verify that design load effects, L_d, do not exceed design resistances, R_d, for any of the considered failure modes in any scenario:

$$L_d \leq R_d$$

A design load F_{dk} is obtained by multiplying the characteristic load by a load factor relevant for the given load category:

$$F_{dk} = \gamma_f \cdot F_k$$

where:

γ_f is load factor; and
F_k is the characteristic load as specified in section 6.4.9 through to section 6.4.12.

A design load effect L_d (e.g. stresses, strains, displacements and vibrations) is the most unfavourable combined load effect derived from the design loads, and may be expressed by:

$$L_d = q(F_{d1}, F_{d2}, \ldots, F_{dN})$$

where q denotes the functional relationship between load and load effect determined by structural analyses.

The design resistance R_d is determined as follows:

$$R_d = \frac{R_k}{\gamma_R \cdot \gamma_C}$$

where:

R_k is the characteristic resistance. In case of materials covered by chapter 7, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength;

γ_R is the resistance factor, defined as $\gamma_R = \gamma_m \cdot \gamma_s$;

γ_m is the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor);

γ_S is the partial resistance factor to take account of the uncertainties on the capacity of the structure, such as the quality of the construction, method considered for determination of the capacity including accuracy of analysis; and

γ_C is the consequence class factor, which accounts for the potential results of failure with regard to release of fuel and possible human injury.

2.2 Fuel containment design shall take into account potential failure consequences. Consequence classes are defined in table 1, to specify the consequences of failure when the mode of failure is related to the Ultimate Limit State, the Fatigue Limit State, or the Accident Limit State.

Table 1: Consequence classes

Consequence class	Definition
Low	Failure implies minor release of the fuel.
Medium	Failure implies release of the fuel and potential for human injury.
High	Failure implies significant release of the fuel and high potential for human injury/fatality.

3 Required Analyses

3.1 Three-dimensional finite element analyses shall be carried out as an integrated model of the tank and the ship hull, including supports and keying system as applicable. All the failure modes shall be identified to avoid unexpected failures. Hydrodynamic analyses shall be carried out to determine the particular ship accelerations and motions in irregular waves, and the response of the ship and its fuel containment systems to these forces and motions.

3.2 Buckling strength analyses of fuel tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with recognized standards. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate out of flatness, plate edge misalignment, straightness, ovality and deviation from true circular form over a specified arc or chord length, as relevant.

3.3 Fatigue and crack propagation analysis shall be carried out in accordance with paragraph 5.1 of this standard.

4 Ultimate Limit States

4.1 Structural resistance may be established by testing or by complete analysis taking account of both elastic and plastic material properties. Safety margins for ultimate strength shall be introduced by partial factors of safety taking account of the contribution of stochastic nature of loads and resistance (dynamic loads, pressure loads, gravity loads, material strength, and buckling capacities).

4.2 Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads shall be considered in the analysis. At least two load combinations with partial load factors as given in table 2 shall be used for the assessment of the ultimate limit states.

Table 2: Partial load factors

Load combination	Permanent loads	Functional loads	Environmental loads
'*a*'	1.1	1.1	0.7
'*b*'	1.0	1.0	1.3

The load factors for permanent and functional loads in load combination '*a*' are relevant for the normally well-controlled and/or specified loads applicable to fuel containment systems such as vapour pressure, fuel weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher.

4.3 For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by the Administration.

4.4 In cases where structural failure of the fuel containment system are considered to imply high potential for human injury and significant release of fuel, the consequence class factor shall be taken as γ_C = 1.2. This value may be reduced if it is justified

through risk analysis and subject to the approval by the Administration. The risk analysis shall take account of factors including, but not limited to, provision of full or partial secondary barrier to protect hull structure from the leakage and less hazards associated with intended fuel. Conversely, higher values may be fixed by the Administration, for example, for ships carrying more hazardous or higher pressure fuel. The consequence class factor shall in any case not be less than 1.0.

4.5 The load factors and the resistance factors used shall be such that the level of safety is equivalent to that of the fuel containment systems as described in sections 6.4.2.1 to 6.4.2.5. This may be carried out by calibrating the factors against known successful designs.

4.6 The material factor γ_m shall in general reflect the statistical distribution of the mechanical properties of the material, and needs to be interpreted in combination with the specified characteristic mechanical properties. For the materials defined in chapter 6, the material factor γ_m may be taken as:

> 1.1 when the characteristic mechanical properties specified by the Administration typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties; or
>
> 1.0 when the characteristic mechanical properties specified by the Administration represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.

4.7 The partial resistance factors γ_{si} shall in general be established based on the uncertainties in the capacity of the structure considering construction tolerances, quality of construction, the accuracy of the analysis method applied, etc.

4.7.1 For design against excessive plastic deformation using the limit state criteria given in paragraph 4.8 of this standard, the partial resistance factors γ_{si} shall be taken as follows:

$$\gamma_{s1} = 0.76 \cdot \frac{B}{\kappa_1}$$

$$\gamma_{s2} = 0.76 \cdot \frac{D}{\kappa_2}$$

$$\kappa_1 = Min\left(\frac{R_m}{R_e} \cdot \frac{B}{A}; 1.0\right)$$

$$\kappa_2 = Min\left(\frac{R_m}{R_e} \cdot \frac{D}{C}; 1.0\right)$$

Factors A, B, C and D are defined in 6.4.15.2.3.1. R_m and R_e are defined in 6.4.12.1.1.3.

The partial resistance factors given above are the results of calibration to conventional type B independent tanks.

4.8 Design against excessive plastic deformation

4.8.1 Stress acceptance criteria given below refer to elastic stress analyses.

4.8.2 Parts of fuel containment systems where loads are primarily carried by membrane response in the structure shall satisfy the following limit state criteria:

$\sigma_m \leq f$
$\sigma_L \leq 1.5f$
$\sigma_b \leq 1.5F$
$\sigma_L + \sigma_b \leq 1.5F$
$\sigma_m + \sigma_b \leq 1.5F$
$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$
$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$
where:

> σ_m = equivalent primary general membrane stress
> σ_L = equivalent primary local membrane stress
> σ_b = equivalent primary bending stress
> σ_g = equivalent secondary stress
>
> $$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_C}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_C}$$

Guidance Note:

The stress summation described above shall be carried out by summing up each stress component (σ_x, σ_y, σ_{xy}), and subsequently the equivalent stress shall be calculated based on the resulting stress components as shown in the example below.

$$\sigma_L + \sigma_b = \sqrt{(\sigma_{Lx} + \sigma_{bx})^2 - (\sigma_{Lx} + \sigma_{bx})(\sigma_{Ly} + \sigma_{by}) + (\sigma_{Ly} + \sigma_{by})^2 + 3(\tau_{Lxy} + \tau_{bxy})^2}$$

4.8.3 Parts of fuel containment systems where loads are primarily carried by bending of girders, stiffeners and plates, shall satisfy the following limit state criteria:

$\sigma_{ms} + \sigma_{bp} \leq 1.25F$ (see notes 1, 2)

$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \leq 1.25F$ (see note 2)

$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_g \leq 3.0F$

Note 1: The sum of equivalent section membrane stress and equivalent membrane stress in primary structure ($\sigma_{ms} + \sigma_{bp}$) will normally be directly available from three-dimensional finite element analyses.

Note 2: The coefficient, 1.25, may be modified by the Administration considering the design concept, configuration of the structure, and the methodology used for calculation of stresses.

where:

σ_{ms} = equivalent section membrane stress in primary structure

σ_{bp} = equivalent membrane stress in primary structure and stress in secondary and tertiary structure caused by bending of primary structure

σ_{bs} = section bending stress in secondary structure and stress in tertiary structure caused by bending of secondary structure

σ_{bt} = section bending stress in tertiary structure

σ_g = equivalent secondary stress

$$f = \frac{R_e}{\gamma_{s1} \cdot \gamma_m \cdot \gamma_C}$$

$$F = \frac{R_e}{\gamma_{s2} \cdot \gamma_m \cdot \gamma_C}$$

The stresses σ_{ms}, σ_{bp}, σ_{bs}, and σ_{bt} are defined in 4.8.4.

Guidance Note:

The stress summation described above shall be carried out by summing up each stress component (σ_x, σ_y, τ_{xy}), and subsequently the equivalent stress shall be calculated based on the resulting stress components.

Skin plates shall be designed in accordance with the requirements of the Administration. When membrane stress is significant, the effect of the membrane stress on the plate bending capacity shall be appropriately considered in addition.

4.8.4 Section stress categories

Normal stress is the component of stress normal to the plane of reference.

Equivalent section membrane stress is the component of the normal stress that is uniformly distributed and equal to the average value of the stress across the cross section of the structure under consideration. If this is a simple shell section, the section membrane stress is identical to the membrane stress defined in paragraph 4.8.2 of this standard.

Section bending stress is the component of the normal stress that is linearly distributed over a structural section exposed to bending action, as illustrated in figure 1.

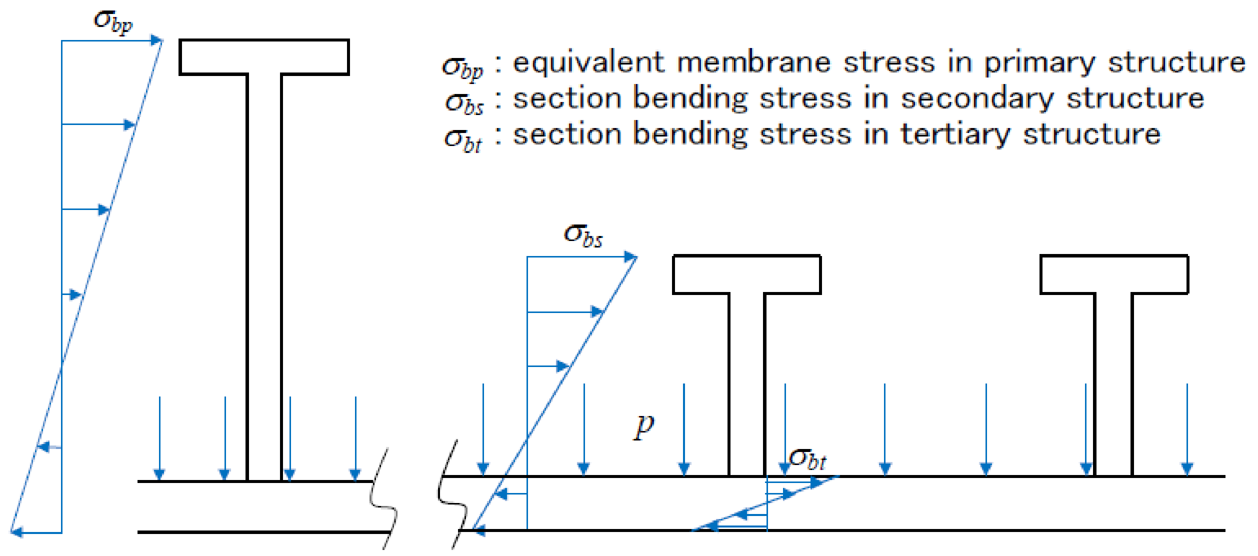

Figure 1: Definition of the three categories of section stress (Stresses σ_{bp} and σ_{bs} are normal to the cross section shown.)

4.9 The same factors γ_C, γ_m, γ_{si} shall be used for design against buckling unless otherwise stated in the applied recognized buckling standard. In any case the overall level of safety shall not be less than given by these factors.

5 Fatigue Limit States

5.1 Fatigue design condition as described in 6.4.12.2 shall be complied with as applicable depending on the fuel containment system concept. Fatigue analysis is required for the fuel containment system designed under 6.4.16 and this standard.

5.2 The load factors for FLS shall be taken as 1.0 for all load categories.

5.3 Consequence class factor γ_C and resistance factor γ_R shall be taken as 1.0.

5.4 Fatigue damage shall be calculated as described in 6.4.12.2.2 to 6.4.12.2.2.5. The calculated cumulative fatigue damage ratio for the fuel containment systems shall be less than or equal to the values given in table 3.

Table 3: Maximum allowable cumulative fatigue damage ratio

	Consequence class		
	Low	Medium	High
C_W	1.0	0.5	0.5*

Note*: Lower value shall be used in accordance with 6.4.12.2.7 to 6.4.12.2.9, depending on the detectability of defect or crack, etc.

5.5 Lower values may be fixed by the Administration.

5.6 Crack propagation analyses are required in accordance with 6.4.12.2.6 to 6.4.12.2.9. The analysis shall be carried out in accordance with methods laid down in a standard recognized by the Administration.

6 Accident Limit States

6.1 Accident design condition as described in 6.4.12.3 shall be complied with as applicable, depending on the fuel containment system concept.

6.2 Load and resistance factors may be relaxed compared to the ultimate limit state considering that damages and deformations can be accepted as long as this does not escalate the accident scenario.

6.3 The load factors for ALS shall be taken as 1.0 for permanent loads, functional loads and environmental loads.

6.4 Loads mentioned in 6.4.9.3.3.8 and 6.4.9.5 need not be combined with each other or with environmental loads, as defined in 6.4.9.4.

6.5 Resistance factor γ_R shall in general be taken as 1.0.

6.6 Consequence class factors γ_C shall in general be taken as defined in paragraph 4.4 of this standard, but may be relaxed considering the nature of the accident scenario.

6.7 The characteristic resistance R_k shall in general be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.

6.8 Additional relevant accident scenarios shall be determined based on a risk analysis.

7 Testing

7.1 Fuel containment systems designed according to this standard shall be tested to the same extent as described in 16.2, as applicable depending on the fuel containment system concept.

Contents

Section
Part B-1

Part B-1

Fuel in the context of the regulations in this part means natural gas, either in its liquefied or gaseous state.

16 Manufacture, Workmanship and Testing

16.1 General

16.1.1 The manufacture, testing, inspection and documentation shall be in accordance with recognized standards and the regulations given in this Code.

LR 16.1-01 The manufacture, testing, inspection and certification are to be in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

16.1.2 Where post-weld heat treatment is specified or required, the properties of the base material shall be determined in the heat treated condition, in accordance with the applicable tables of chapter 7, and the weld properties shall be determined in the heat treated condition in accordance with 16.3. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Administration.

LR 16.1-02 A relaxation in the requirements for Charpy V-notch impact tests will be permitted for smaller fuel tanks or process pressure vessels which are post-weld heat treated. The extent of this relaxation will be specially considered for each application and will depend on the grade of steel and thickness involved.

16.2 General test regulations and specifications

16.2.1 Tensile test

16.2.1.1 Tensile testing shall be carried out in accordance with recognized standards.

16.2.1.2 Tensile strength, yield stress and elongation shall be to the satisfaction of the Administration. For carbon-manganese steel and other materials with definitive yield points, consideration shall be given to the limitation of the yield to tensile ratio.

LR 16.2-01 The grades of materials used are to generally have mechanical properties complying with the appropriate requirements as given in the Rules for Materials. Provided that the material has satisfactory ductility, there will be no limitation on the yield to tensile stress ratio, except for carbon–manganese steel grades for low temperature service. For carbon–manganese steel grades for low temperature service, the yield to tensile ratio requirement of *Ch 3, 6 Ferritic steels for low temperature service* of the *Rules for the Manufacture, Testing and Certification of Materials* is to be met.

16.2.2 Toughness test

16.2.2.1 Acceptance tests for metallic materials shall include Charpy V-notch toughness tests unless otherwise specified by the Administration. The specified Charpy V-notch regulations are minimum average energy values for three full size (10 mm × 10 mm) specimens and minimum single energy values for individual specimens. Dimensions and tolerances of Charpy V-notch specimens shall be in accordance with recognized standards. The testing and regulations for specimens smaller than 5.0 mm in size shall be in accordance with recognized standards. Minimum average values for sub-sized specimens shall be:

Charpy V-notch specimen size (mm)	Minimum average energy of three specimens
10 x 10	KV
10 x 7.5	5/6 KV
10 x 5.0	2/3 KV

where:
KV = the energy values (J) specified in tables 7.1 to 7.4.

Only one individual value may be below the specified average value, provided it is not less than 70% of that value.

16.2.2.2 For base metal, the largest size Charpy V-notch specimens possible for the material thickness shall be machined with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness and the length of the notch perpendicular to the surface as shown in figure 16.1.

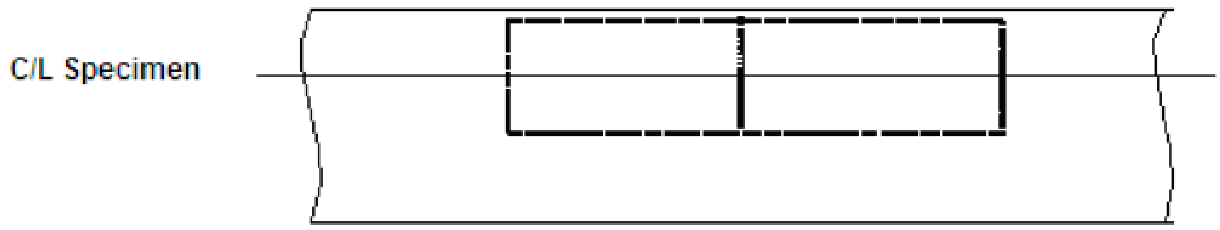

Figure 16.1 – Orientation of base metal test specimen

16.2.2.3 For a weld test specimen, the largest size Charpy V-notch specimens possible for the material thickness shall be machined, with the specimens located as near as practicable to a point midway between the surface and the centre of the thickness. In all cases the distance from the surface of the material to the edge of the specimen shall be approximately 1 mm or greater. In addition, for double-V butt welds, specimens shall be machined closer to the surface of the second welded section. The specimens shall be taken generally at each of the following locations, as shown in figure 16.2, on the centreline of the welds, the fusion line and 1 mm, 3 mm and 5 mm from the fusion line.

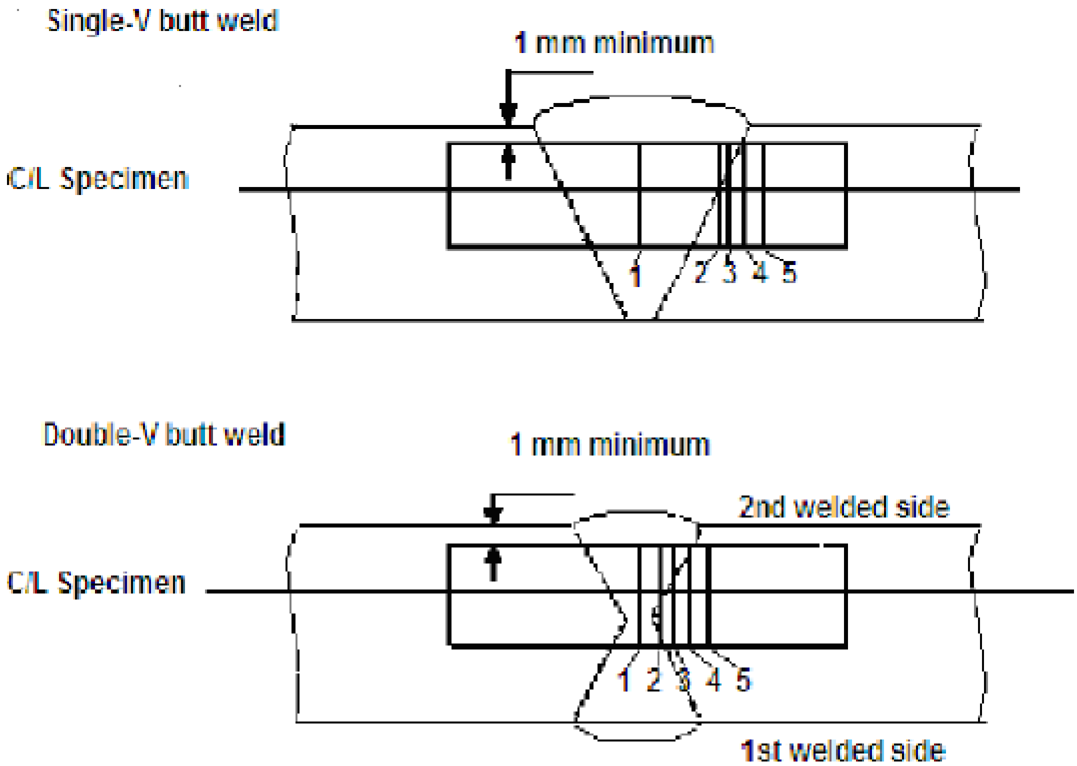

Figure 16.2 – Orientation of weld test specimen

Notch locations in figure 16.2:

.1 centreline of the weld;

.2 on fusion line;

.3 in heat-affected zone (HAZ), 1 mm from fusion line;

.4 in HAZ, 3 mm from fusion line; and

.5 in HAZ, 5 mm from fusion line.

16.2.2.4 If the average value of the three initial Charpy V-notch specimens fails to meet the stated regulations, or the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, three additional specimens from the same material may be tested and the results combined with those previously obtained to form a new average. If this new average complies with the regulations and if no more than two individual results are lower, than the required average and no more than one result is lower than the required value for a single specimen, the piece or batch may be accepted.

LR 16.2-02 Material toughness is to be determined by the Charpy V-notch impact test in accordance with the Rules for Materials. In addition, LR may also request other types of tests, such as drop weight or crack tip opening displacement test.

16.2.3 Bend test

16.2.3.1 The bend test may be omitted as a material acceptance test, but is required for weld tests. Where a bend test is performed, this shall be done in accordance with recognized standards.

LR 16.2-03 Bend tests are to be taken only when such tests are required in the *Rules for Materials*.

16.2.3.2 The bend tests shall be transverse bend tests, which may be face, root or side bends at the discretion of the Administration. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels.

16.2.4 Section observation and other testing

Macrosection, microsection observations and hardness tests may also be required by the Administration, and they shall be carried out in accordance with recognized standards, where required.

LR 16.2-04 These tests are to be carried out when required by the Rules for Materials and when required according to the scope of approval of the fuel containment system.

16.3 Welding of metallic materials and non-destructive testing for the fuel containment system

LR 16.3-01 Unless otherwise specified below, all welded construction is to be in accordance with *Chapter 13* of the Rules for Materials.

LR 16.3-02 Unless otherwise specified in these Rules, welding procedure tests are to be performed in accordance with the requirements of *Chapter 12* of the Rules for Materials. Generally, impact tests from aluminium welded joint are not required. For austenitic stainless steel welded joint, impact tests are not required from the heat affected zone.

16.3.1 General

This section shall apply to primary and secondary barriers only, including the inner hull where this forms the secondary barrier. Acceptance testing is specified for carbon, carbon-manganese, nickel alloy and stainless steels, but these tests may be adapted for other materials. At the discretion of the Administration, impact testing of stainless steel and aluminium alloy weldments may be omitted and other tests may be specially required for any material.

16.3.2 Welding consumables

Consumables intended for welding of fuel tanks shall be in accordance with recognized standards. Deposited weld metal tests and butt weld tests shall be required for all consumables. The results obtained from tensile and Charpy V-notch impact tests shall be in accordance with recognized standards. The chemical composition of the deposited weld metal shall be recorded for information.

LR 16.3-03 Welding consumables are to be approved by LR in accordance with *Chapter 11* of the Rules for Materials.

16.3.3 Welding procedure tests for fuel tanks and process pressure vessels

16.3.3.1 Welding procedure tests for fuel tanks and process pressure vessels are required for all butt welds.

16.3.3.2 The test assemblies shall be representative of:

.1 each base material;

.2 each type of consumable and welding process; and

.3 each welding position.

16.3.3.3 For butt welds in plates, the test assemblies shall be so prepared that the rolling direction is parallel to the direction of welding. The range of thickness qualified by each welding procedure test shall be in accordance with recognized standards. Radiographic or ultrasonic testing may be performed at the option of the fabricator.

LR 16.3-04 Welding procedure tests are to be performed in accordance with the requirements of *Chapter 12* of the Rules for Materials, except where indicated otherwise in these Rules. Mechanical tests for butt welds are to be in accordance with 16.3.3.4.

16.3.3.4 The following welding procedure tests for fuel tanks and process pressure vessels shall be done in accordance with 16.2 with specimens made from each test assembly:

.1 cross-weld tensile tests;

.2 longitudinal all-weld testing where required by the recognized standards;

.3 transverse bend tests, which may be face, root or side bends. However, longitudinal bend tests may be required in lieu of transverse bend tests in cases where the base material and weld metal have different strength levels;

.4 one set of three Charpy V-notch impacts, generally at each of the following locations, as shown in figure 16.2:

  .1 centreline of the welds;

  .2 fusion line;

  .3 1 mm from the fusion line;

  .4 3 mm from the fusion line; and

  .5 5 mm from the fusion line;

.5 macrosection, microsection and hardness survey may also be required.

LR 16.3-05 Additionally, an all-weld metal tensile test is required from welding procedure tests for Type C independent fuel tanks. A macrosection and hardness survey is required for all welding procedure tests, except that the hardness survey is not required for austenitic stainless steel. Generally, microsections are not required.

LR 16.3-06 For alloys where the weld metal has a lower tensile strength than that of the parent metal, and such an application has prior approval by LR, the transverse weld tensile strength is not to be less than the specified design tensile strength.

16.3.3.5 Each test shall satisfy the following:

.1 tensile tests: cross-weld tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. For aluminium alloys, reference shall be made to 6.4.12.1.1.3 with regard to the regulations for weld metal strength of under-matched welds (where the weld metal has a lower tensile strength than the parent metal). In every case, the position of fracture shall be recorded for information;

.2 bend tests: no fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test pieces; and

.3 Charpy V-notch impact tests: Charpy V-notch tests shall be conducted at the temperature prescribed for the base material being joined. The results of weld metal impact tests, minimum average energy (KV), shall be no less than 27 J. The weld metal regulations for sub-size specimens and single energy values shall be in accordance with 16.2.2. The results of fusion line and heat affected zone impact tests shall show a minimum average energy (KV) in accordance with the transverse or longitudinal regulations of the base material, whichever is applicable, and for sub-size specimens, the minimum average energy (KV) shall be in accordance with 16.2.2. If the material thickness does not permit machining either full-size or standard sub-size specimens, the testing procedure and acceptance standards shall be in accordance with recognized standards.

LR 16.3-07 For aluminium alloys, the bend test required in 16.3.3.4.3 is to be carried out over a former with D/t according to *Ch 12,4* of the Rules for Materials.

LR 16.3-08 Bend tests revealing small openings up to a maximum of 3 mm in any direction are acceptable.

16.3.3.6 Procedure tests for fillet welding shall be in accordance with recognized standards. In such cases, consumables shall be so selected that exhibit satisfactory impact properties.

LR 16.3-09 *Ch 12* of the Rules for Materials is to be followed for procedure tests for fillet welding, and LR approved welding consumables are to be used.

16.3.4 Welding procedure tests for piping

Welding procedure tests for piping shall be carried out and shall be similar to those detailed for fuel tanks in 16.3.3.

16.3.5 Production weld tests

16.3.5.1 For all fuel tanks and process pressure vessels except membrane tanks, production weld tests shall generally be performed for approximately each 50 m of butt-weld joints and shall be representative of each welding position. For secondary barriers, the same type production tests as required for primary tanks shall be performed, except that the number of tests may be reduced subject to agreement with the Administration. Tests, other than those specified in 16.3.5.2 to 16.3.5.5 may be required for fuel tanks or secondary barriers.

16.3.5.2 The production tests for types A and B independent tanks shall include bend tests and, where required for procedure tests, one set of three Charpy V-notch tests. The tests shall be made for each 50 m of weld. The Charpy V-notch tests shall be made with specimens having the notch alternately located in the centre of the weld and in the heat affected zone (most critical location based on procedure qualification results). For austenitic stainless steel, all notches shall be in the centre of the weld.

LR 16.3-10 The production weld tests shall satisfy the applicable requirements of 16.3.3.5.

16.3.5.3 For type C independent tanks and process pressure vessels, transverse weld tensile tests are required in addition to the tests listed in 16.3.5.2. Tensile tests shall meet regulation 16.3.3.5.

LR 16.3-11 In addition, an all-weld metal tensile test for Type C independent fuel tanks and Class 1 and Class 2/1 process pressure vessels is required.

LR 16.3-12 In addition, a macrosection examination and hardness survey are required according to *Ch 13,4.8* of the Rules for Materials.

16.3.5.4 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the production welds as defined in the material manufacturers quality manual (QM).

16.3.5.5 The test regulations for membrane tanks are the same as the applicable test regulations listed in 16.3.3.

LR 16.3-13 Requirements for production tests from membrane tanks are to be agreed with LR prior to manufacture.

LR 16.3-14 Unless otherwise stated below, all welds are to be subject to non-destructive examination in accordance with the requirements of *Chapter 13* of the Rules for Materials.

16.3.6 Non-destructive testing

16.3.6.1 All test procedures and acceptance standards shall be in accordance with recognized standards, unless the designer specifies a higher standard in order to meet design assumptions. Radiographic testing shall be used in principle to detect internal defects. However, an approved ultrasonic test procedure in lieu of radiographic testing may be conducted, but in addition supplementary radiographic testing at selected locations shall be carried out to verify the results. Radiographic and ultrasonic testing records shall be retained.

16.3.6.2 For type A independent tanks where the design temperature is below -20°C, and for type B independent tanks, regardless of temperature, all full penetration butt welds of the shell plating of fuel tanks shall be subjected to non-destructive testing suitable to detect internal defects over their full length. Ultrasonic testing in lieu of radiographic testing may be carried out under the same conditions as described in 16.3.6.1.

16.3.6.3 In each case the remaining tank structure, including the welding of stiffeners and other fittings and attachments, shall be examined by magnetic particle or dye penetrant methods as considered necessary.

16.3.6.4 For type C independent tanks, the extent of non-destructive testing shall be total or partial according to recognized standards, but the controls to be carried out shall not be less than the following:

.1 Total non-destructive testing referred to in 6.4.15.3.2.1.3

Radiographic testing:

.1 all butt welds over their full length.

Non-destructive testing for surface crack detection:

.2 all welds over 10% of their length;

.3 reinforcement rings around holes, nozzles, etc. over their full length.

As an alternative, ultrasonic testing, as described in 16.3.6.1, may be accepted as a partial substitute for the radiographic testing. In addition, the Administration may require total ultrasonic testing on welding of reinforcement rings around holes, nozzles, etc.

.2 Partial non-destructive testing referred to in 6.4.15.3.2.1.3:

Radiographic testing:

.1 all butt welded crossing joints and at least 10% of the full length of butt welds at selected positions uniformly distributed.

Non-destructive testing for surface crack detection:

.2 reinforcement rings around holes, nozzles, etc. over their full length.

Ultrasonic testing:

.3 as may be required by the Administration in each instance.

LR 16.3-15 Non-destructive testing is to meet the requirements of *Ch 13,4* of the Rules for Materials for Class 1 pressure vessels.

16.3.6.5 The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the non-destructive testing of welds, as defined in the material manufacturer's quality manual (QM).

16.3.6.6 Inspection of piping shall be carried out in accordance with the regulations of chapter 7.

16.3.6.7 The secondary barrier shall be non-destructive tested for internal defects as considered necessary. Where the outer shell of the hull is part of the secondary barrier, all sheer strake butts and the intersections of all butts and seams in the side shell shall be tested by radiographic testing.

16.4 Other regulations for construction in metallic materials

16.4.1 General

Inspection and non-destructive testing of welds shall be in accordance with regulations in 16.3.5 and 16.3.6. Where higher standards or tolerances are assumed in the design, they shall also be satisfied.

16.4.2 Independent tank

For type C tanks and type B tanks primarily constructed of bodies of revolution the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with recognized standards. The tolerances shall also be related to the buckling analysis referred to in 6.4.15.2.3.1 and 6.4.15.3.3.2.

LR 16.4-01 For Type C independent tanks, manufacture and workmanship are to satisfy the requirements of *Ch 13,4* of the Rules for Materials for Class 1 pressure vessels.

LR 16.4-02 For Type C independent tanks, the post-weld heat treatment is to be performed to the requirements of *Ch 13,4.10* and *4.11* in the Rules for Materials.

16.4.3 Secondary barriers

During construction the regulations for testing and inspection of secondary barriers shall be approved or accepted by the Administration (see also 6.4.4.5 and 6.4.4.6).

16.4.4 Membrane tanks

The quality assurance/quality control (QA/QC) program shall ensure the continued conformity of the weld procedure qualification, design details, materials, construction, inspection and production testing of components. These standards and procedures shall be developed during the prototype testing programme.

16.5 Testing

16.5.1 Testing and inspections during construction

16.5.1.1 All liquefied gas fuel tanks and process pressure vessels shall be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with 16.5.2 to 16.5.5, as applicable for the tank type.

16.5.1.2 All tanks shall be subject to a tightness test which may be performed in combination with the pressure test referred to in 16.5.1.1.

16.5.1.3 The gas tightness of the fuel containment system with reference to 6.3.3 shall be tested.

16.5.1.4 Regulations with respect to inspection of secondary barriers shall be decided by the Administration in each case, taking into account the accessibility of the barrier (see also 6.4.4).

16.5.1.5 The Administration may require that for ships fitted with novel type B independent tanks, or tanks designed according to 6.4.16 at least one prototype tank and its support shall be instrumented with strain gauges or other suitable equipment to confirm stress levels during the testing required in 16.5.1.1. Similar instrumentation may be required for type C independent tanks, depending on their configuration and on the arrangement of their supports and attachments.

16.5.1.6 The overall performance of the fuel containment system shall be verified for compliance with the design parameters during the first LNG bunkering, when steady thermal conditions of the liquefied gas fuel are reached, in accordance with the requirements of the Administration. Records of the performance of the components and equipment, essential to verify the design parameters, shall be maintained on board and be available to the Administration.

LR 16.5-01 The overall performance of the fuel containment system is to be verified for compliance with the design parameters during initial trials. The initial trials are to be witnessed by LR's Surveyors, and are to demonstrate that the system is capable of being inerted, cooled and bunkered in a satisfactory manner, and that all safety devices function correctly. The temperature at which these tests are carried out is to be at or near the minimum fuel temperature.

LR 16.5-02 Where refrigeration plant is fitted, or other means to control the fuel tank(s) vapour pressure, its operation is to be demonstrated to the Surveyors. Records of the plant performance taken during the first bunkered voyage at minimum temperature are to be submitted. The above tests may be carried out in conjunction with the vessel's normal trading commitments. Normal voyage logs of plant performance are to be maintained for examination by the Surveyors when requested.

16.5.1.7 The fuel containment system shall be inspected for cold spots during or immediately following the first LNG bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked shall be carried out in accordance with the requirements of the Administration.

16.5.1.8 Heating arrangements, if fitted in accordance with 6.4.13.1.1.3 and 6.4.13.1.1.4, shall be tested for required heat output and heat distribution.

16.5.2 Type A independent tanks

All type A independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing. This test shall be performed such that the stresses approximate, as far as practicable, the design stresses, and that the pressure at the top of the tank corresponds at least to the MARVS. When a hydropneumatic test is performed, the conditions shall simulate, as far as practicable, the design loading of the tank and of its support structure including dynamic components, while avoiding stress levels that could cause permanent deformation.

LR 16.5-03 If a hydropneumatic test is utilised, the head of water, h_{HP}, required to model the design pressure, P_{eq}, is to be taken as:

$$h_{HP} = \frac{102\left(P_{eq} - P_{air}\right)}{RD} + y$$

where

h_{HP} = hydropneumatic test head of water, in metres, measured from bottom of fuel tank

P_{eq} = design pressure, in MPa, at location under consideration as derived from 6.4.9.3.3.1.4

P_{air} = air test pressure, in MPa

RD = relative density

= ρ / ρ_{fw}

ρ = density of test fluid

ρ_{fw} = density of freshwater to be taken as 1000 kg/m^3 at 4°C

y = the vertical distance, in metres, from bottom of tank to the location under consideration, *see* Fig. LR 16.2.

For a given head of water the load P_{HP}, in MPa, at the location under consideration would be:

$$P_{\mathrm{HP}} = P_{air} + \left(h_{\mathrm{HP}} - y\right)\frac{RD}{102}$$

Care is to be given that the ratio

$$\frac{P_{HP}}{P_{eq}} \leq 1,0 \text{ at any point around the tank.}$$

LR 16.5-04 If a hydrostatic test is utilised, the head of water, h_{HS}, required to model the design pressure, P_{eq}, is to be taken as:

$$h_{\mathrm{HS}} = \frac{102P_{\mathrm{eq}}}{RD} - \left(h - y\right)$$

where

h_{HS} = hydrostatic test head of water, in metres, measured above top of fuel tank of depth h

h = height of tank, in metres, Fig. LR 16.2.

For a given head of water, the load P_{HS}, in MPa, at the location under consideration would be:

$$P_{\mathrm{HS}} = \left(h_{\mathrm{HS}} + (h - y)\right)\frac{RD}{102}$$

Care is to be given that the ratio

$$\frac{P_{\mathrm{HS}}}{P_{\mathrm{eq}}} \leq 1,0 \text{ at any point arond the tank.}$$

LR 16.5-05 The test pressure is to be not less than the MARVS and is not normally to exceed the relief valve harbour setting:

$$P_{\mathrm{max}} = \left(\frac{t_{\mathrm{min}} - 1}{0,04 s f \sqrt{k}}\right)^2 \text{ MPa}$$

The design pressure is not to be exceeded at any point, and the test is to adequately load all areas of the tank. *See also Pt 3, Ch 1,9.6.2* in the Rules for Ships. When testing takes place after installation of the tanks on board ship, care is to be taken that the test head does not result in excessive local loading on the hull structure. For this purpose, when the fuel tanks are centrally divided with a non-perforated bulkhead, consideration will be given to testing the port and starboard sides of the tank independently.

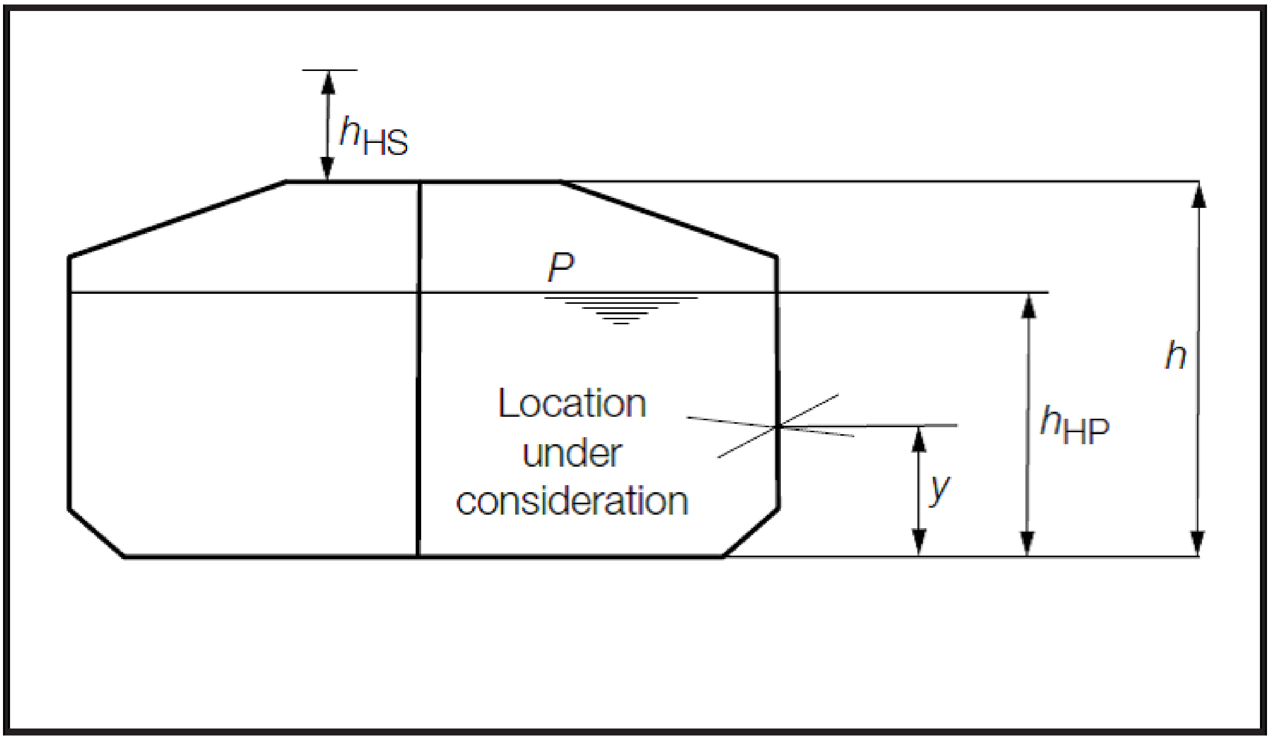

Fig. LR 16.2

16.5.3 Type B independent tanks

Type B independent tanks shall be subjected to a hydrostatic or hydro-pneumatic pressure testing as follows:

.1 The test shall be performed as required in 16.5.2 for type A independent tanks.

.2 In addition, the maximum primary membrane stress or maximum bending stress in primary members under test conditions shall not exceed 90% of the yield strength of the material (as fabricated) at the test temperature. To ensure that this condition is satisfied, when calculations indicate that this stress exceeds 75% of the yield strength the test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment.

16.5.4 Type C independent tanks and other pressure vessels

16.5.4.1 Each pressure vessel shall be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1.5 P_0. In no case during the pressure test shall the calculated primary membrane stress at any point exceed 90% of the yield strength of the material at the test temperature. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the test of the first of a series of identical tanks shall be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

16.5.4.2 The temperature of the water used for the test shall be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

16.5.4.3 The pressure shall be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

16.5.4.4 Where necessary for liquefied gas fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in 16.5.4.1 to 16.5.4.3.

LR 16.5-06 When a hydropneumatic test is performed, the conditions are to simulate, so far as practicable, the actual loading of the tank and its supports.

16.5.4.5 Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, regulation in 16.5.4.1 shall be fully complied with.

16.5.4.6 After completion and assembly, each pressure vessel and its related fittings shall be subjected to an adequate tightness test, which may be performed in combination with the pressure testing referred to in 16.5.4.1 or 16.5.4.4 as applicable.

16.5.4.7 Pneumatic testing of pressure vessels other than liquefied gas fuel tanks shall be considered on an individual case basis. Such testing shall only be permitted for those vessels designed or supported such that they cannot be safely filled with water, or for those vessels that cannot be dried and are to be used in a service where traces of the testing medium cannot be tolerated.

16.5.5 Membrane tanks

16.5.5.1 *Design development testing*

16.5.5.1.1 The design development testing required in 6.4.15.4.1.2 shall include a series of analytical and physical models of both the primary and secondary barriers, including corners and joints, tested to verify that they will withstand the expected combined strains due to static, dynamic and thermal loads at all filling levels. This will culminate in the construction of a prototype scaled model of the complete liquefied gas fuel containment system. Testing conditions considered in the analytical and physical model shall represent the most extreme service conditions the liquefied gas fuel containment system will be likely to encounter over its life. Proposed acceptance criteria for periodic testing of secondary barriers required in 6.4.4 may be based on the results of testing carried out on the prototype scaled model.

16.5.5.1.2 The fatigue performance of the membrane materials and representative welded or bonded joints in the membranes shall be determined by tests. The ultimate strength and fatigue performance of arrangements for securing the thermal insulation system to the hull structure shall be determined by analyses or tests.

16.5.5.2 *Testing*

.1 In ships fitted with membrane liquefied gas fuel containment systems, all tanks and other spaces that may normally contain liquid and are adjacent to the hull structure supporting the membrane, shall be hydrostatically tested.

.2 All hold structures supporting the membrane shall be tested for tightness before installation of the liquefied gas fuel containment system.

.3 Pipe tunnels and other compartments that do not normally contain liquid need not be hydrostatically tested.

16.6 Welding, post-weld heat treatment and non-destructive testing

16.6.1 General

Welding shall be carried out in accordance with 16.3.

16.6.2 Post-weld heat treatment

Post-weld heat treatment shall be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Administration may waive the regulations for thermal stress relieving of pipes with wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

LR 16.6-01 Post-weld heat treatment is required for all butt welds in pipes carrying natural gas contaminated with hydrogen sulphide which are constructed in steel with a minimum tensile strength exceeding 410 N/mm^2.

LR 16.6-02 Unless otherwise stated below, all welds are to be subject to non-destructive examination in accordance with the requirements of *Ch 13* of the Rules for Materials.

16.6.3 Non-destructive testing

In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, as necessary for proving that the welding has been carried out correctly and according to the regulations in this paragraph, the following tests shall be required:

.1 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with;

.1 design temperatures colder than minus 10°C; or

.2 design pressure greater than 1.0 MPa; or

.3 gas supply pipes in ESD protected machinery spaces; or

.4 inside diameters of more than 75 mm; or

.5 wall thicknesses greater than 10 mm.

.2 When such butt welded joints of piping sections are made by automatic welding procedures approved by the Administration, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed the extent of examination shall be increased to 100% and shall

include inspection of previously accepted welds. This approval can only be granted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently.

.3 The radiographic or ultrasonic inspection regulation may be reduced to 10% for butt-welded joints in the outer pipe of double-walled fuel piping.

.4 For other butt-welded joints of pipes not covered by 16.6.3.1 and 16.6.3.3, spot radiographic or ultrasonic inspection or other non-destructive tests shall be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes shall be subjected to radiographic or ultrasonic inspection.

LR 16.6-03 Non-destructive testing is to meet the requirements of *Ch 13,5* of the Rules for Materials for pressure piping.

16.7 Testing regulations

16.7.1 Type testing of piping components

Valves

Each type of piping component intended to be used at a working temperature below minus 55°C shall be subject to the following type tests:

.1 Each size and type of valve shall be subjected to seat tightness testing over the full range of operating pressures and temperatures, at intervals, up to the rated design pressure of the valve. Allowable leakage rates shall be to the requirements of the Administration During the testing satisfactory operation of the valve shall be verified.

.2 The flow or capacity shall be certified to a recognized standard for each size and type of valve.

.3 Pressurized components shall be pressure tested to at least 1.5 times the design pressure.

.4 For emergency shutdown valves, with materials having melting temperatures lower than 925°C, the type testing shall include a fire test to a standard at least equivalent to those acceptable to the Organization.[32]

LR 16.7-01 For further details on the type testing of piping components, reference is to be made to LR 5.13-01, LR 5.13-02, LR 5.13-03 and LR 5.13-04 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, July 2019*

16.7.2 Expansion bellows

The following type tests shall be performed on each type of expansion bellows intended for use on fuel piping outside the fuel tank as found acceptable in 7.3.6.4.3.1. and .3 and where required by the Administration, on those installed within the fuel tanks:

.1 Elements of the bellows, not pre-compressed, but axially restrained shall be pressure tested at not less than five times the design pressure without bursting. The duration of the test shall not be less than five minutes.

.2 A pressure test shall be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at the minimum design temperature and twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation.

.3 A cyclic test (thermal movements) shall be performed on a complete expansion joint, which shall withstand at least as many cycles under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.

.4 A cyclic fatigue test (ship deformation, ship accelerations and pipe vibrations) shall be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

LR 16.7-02 For further details on the type testing of expansion bellows, reference is to be made to LR 5.13-05 and LR 5.13-06 of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, July 2019*

16.7.3 System testing regulations

[32] Refer to the recommendations by the International Organization for Standardization, in particular publications:

ISO 19921:2005, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods

ISO 19922:2005, Ships and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench

16.7.3.1 The regulations for testing in this section apply to fuel piping inside and outside the fuel tanks. However, relaxation from these regulations for piping inside fuel tanks and open ended piping may be accepted by the Administration.

16.7.3.2 After assembly, all fuel piping shall be subjected to a strength test with a suitable fluid. The test pressure shall be at least 1.5 times the design pressure for liquid lines and 1.5 times the maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board shall be tested to at least 1.5 times the design pressure.

16.7.3.3 After assembly on board, the fuel piping system shall be subjected to a leak test using air, or other suitable medium to a pressure depending on the leak detection method applied.

16.7.3.4 In double wall fuel piping systems the outer pipe or duct shall also be pressure tested to show that it can withstand the expected maximum pressure at pipe rupture.

LR 16.7-03 The pressure test required by 16.7.3.4 is to be carried out after assembly on board. Where this is not feasible, then consideration will be given to pressure testing of individual piping or ductwork prior to installation providing calculations verifying the design pressure of the ducting is submitted and the piping is satisfactorily leak tested after completion of installation.

16.7.3.5 All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, shall be tested under normal operating conditions not later than at the first bunkering operation, in accordance with the requirements of the Administration.

LR 16.7-04 For gas fuel system with pressure no greater than 1 MPa, the gas fuel piping in the machinery space is to be tested in place by hydraulic pressure to 0,7 MPa or twice the working pressure, whichever is the greater. Subsequently, the lines are to be tested by air at the working pressure using soapy water, or equivalent, to verify that all joints are absolutely tight.

LR 16.7-05 For gas fuel systems with pressure greater than 1 MPa, all gas fuel piping shall be subjected to a strength test with a suitable fluid. The test pressure shall be at least 1,5 times the design pressure for liquid lines and 1,5 times the maximum system working pressure for vapour lines. When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board shall be tested to at least 1,5 times the design pressure.

LR 16.7-06 After assembly on board, the fuel piping system shall be subjected to a leak test using air, or another suitable medium to a pressure depending on the leak detection method applied.

16.7.3.6 Emergency shutdown valves in liquefied gas piping systems shall close fully and smoothly within 30 s of actuation. Information about the closure time of the valves and their operating characteristics shall be available on board, and the closing time shall be verifiable and repeatable.

16.7.3.7 The closing time of the valve referred to in 8.5.8 and 15.4.2.2 (i.e. time from shutdown signal initiation to complete valve closure) shall not be greater than:

$$\frac{3600U}{BR}\left(second\right)$$

where:

U = ullage volume at operating signal level (m^3);

BR = maximum bunkering rate agreed between ship and shore facility (m^3/h); or

5 seconds, whichever is the least.

The bunkering rate shall be adjusted to limit surge pressure on valve closure to an acceptable level, taking into account the bunkering hose or arm, the ship and the shore piping systems, where relevant.

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Section
Part C-1

■

Part C-1

Fuel in the context of the regulations in this part means natural gas, either in its liquefied or gaseous state.

17 Drills and Emergency Exercises

Drills and emergency exercises on board shall be conducted at regular intervals.

Such gas-related exercises could include for example:

.1 tabletop exercise;

.2 review of fueling procedures based in the fuel handling manual required by 18.2.3;

.3 responses to potential contingencies;

.4 tests of equipment intended for contingency response; and

.5 reviews that assigned seafarers are trained to perform assigned duties during fuelling and contingency response.

Gas related exercises may be incorporated into periodical drills required by SOLAS.

The response and safety system for hazards and accident control shall be reviewed and tested.

18 Operation

18.1 Goal

The goal of this chapter is to ensure that operational procedures for the loading, storage, operation, maintenance, and inspection of systems for gas or low-flashpoint fuels minimize the risk to personnel, the ship and the environment and that are consistent with practices for a conventional oil fuelled ship whilst taking into account the nature of the liquid or gaseous fuel.

18.2 Functional requirements

This chapter relates to the functional requirements in 3.2.1 to 3.2.3, 3.2.9, 3.2.11, 3.2.15, 3.2.16 and 3.2.17. In particular the following apply:

.1 a copy of this Code, or national regulations incorporating the provisions of this Code, shall be on board every ship covered by this Code;

.2 maintenance procedures and information for all gas related installations shall be available on board;

.3 the ship shall be provided with operational procedures including a suitably detailed fuel handling manual, such that trained personnel can safely operate the fuel bunkering, storage and transfer systems; and

.4 the ship shall be provided with suitable emergency procedures.

18.3 Regulations for maintenance

18.3.1 Maintenance and repair procedures shall include considerations with respect to the tank location and adjacent spaces (see chapter 5).

18.3.2 In-service survey, maintenance and testing of the fuel containment system are to be carried out in accordance with the inspection/survey plan required by 6.4.1.8.

18.3.3 The procedures and information shall include maintenance of electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces shall be performed in accordance with a recognized standard.[33]

18.4 Regulations for bunkering operations

18.4.1 Responsibilities

18.4.1.1 Before any bunkering operation commences, the master of the receiving ship or his representative and the representative of the bunkering source (Persons In Charge, PIC) shall:

.1 agree in writing the transfer procedure, including cooling down and if necessary, gassing up; the maximum transfer rate at all stages and volume to be transferred;

.2 agree in writing action to be taken in an emergency; and

.3 complete and sign the bunker safety check-list.

18.4.1.2 Upon completion of bunkering operations the ship PIC shall receive and sign a Bunker Delivery Note for the fuel delivered, containing at least the information specified in the annex to part C-1, completed and signed by the bunkering source PIC.

18.4.2 Overview of control, automation and safety systems

18.4.2.1 The fuel handling manual required by 18.2.3 shall include but is not limited to:

.1 overall operation of the ship from dry-dock to dry-dock, including procedures for system cool down and warm up, bunker loading and, where appropriate, discharging, sampling, inerting and gas freeing;

.2 bunker temperature and pressure control, alarm and safety systems;

.3 system limitations, cool down rates and maximum fuel storage tank temperatures prior to bunkering, including minimum fuel temperatures, maximum tank pressures, transfer rates, filling limits and sloshing limitations;

.4 operation of inert gas systems;

.5 firefighting and emergency procedures: operation and maintenance of firefighting systems and use of extinguishing agents;

.6 specific fuel properties and special equipment needed for the safe handling of the particular fuel;

.7 fixed and portable gas detection operation and maintenance of equipment;

.8 emergency shutdown and emergency release systems, where fitted; and

.9 a description of the procedural actions to take in an emergency situation, such as leakage, fire or potential fuel stratification resulting in rollover.

18.4.2.2 A fuel system schematic/piping and instrumentation diagram (P&ID) shall be reproduced and permanently mounted in the ship's bunker control station and at the bunker station.

18.4.3 Pre-bunkering verification

18.4.3.1 Prior to conducting bunkering operations, pre-bunkering verification including, but not limited to the following, shall be carried out and documented in the bunker safety checklist:

.1 all communications methods, including ship shore link (SSL), if fitted;

[33] Refer to IEC 60079 17:2007 Explosive atmospheres – part 17: Electrical installations inspection and maintenance.

.2 operation of fixed gas and fire detection equipment;

.3 operation of portable gas detection equipment;

.4 operation of remote controlled valves; and

.5 inspection of hoses and couplings.

18.4.3.2 Documentation of successful verification shall be indicated by the mutually agreed and executed bunkering safety checklist signed by both PIC's.

18.4.4 Ship bunkering source communications

18.4.4.1 Communications shall be maintained between the ship PIC and the bunkering source PIC at all times during the bunkering operation. In the event that communications cannot be maintained, bunkering shall stop and not resume until communications are restored.

18.4.4.2 Communication devices used in bunkering shall comply with recognized standards for such devices acceptable to the Administration.

18.4.4.3 PIC's shall have direct and immediate communication with all personnel involved in the bunkering operation.

18.4.4.4 The ship shore link (SSL) or equivalent means to a bunkering source provided for automatic ESD communications, shall be compatible with the receiving ship and the delivering facility ESD system.[34]

18.4.5 Electrical bonding

Hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering shall be electrically continuous, suitably insulated and shall provide a level of safety compliant with recognized standards.[35]

18.4.6 Conditions for transfer

18.4.6.1 Warning signs shall be posted at the access points to the bunkering area listing fire safety precautions during fuel transfer.

18.4.6.2 During the transfer operation, personnel in the bunkering manifold area shall be limited to essential staff only. All staff engaged in duties or working in the vicinity of the operations shall wear appropriate personal protective equipment (PPE). A failure to maintain the required conditions for transfer shall be cause to stop operations and transfer shall not be resumed until all required conditions are met.

18.4.6.3 Where bunkering is to take place via the installation of portable tanks, the procedure shall provide an equivalent level of safety as integrated fuel tanks and systems. Portable tanks shall be filled prior to loading on board the ship and shall be properly secured prior to connection to the fuel system.

18.4.6.4 For tanks not permanently installed in the ship, the connection of all necessary tank systems (piping, controls, safety system, relief system, etc.) to the fuel system of the ship is part of the "bunkering" process and shall be finished prior to ship departure from the bunkering source. Connecting and disconnecting of portable tanks during the sea voyage or manoeuvring is not permitted.

18.5 Regulations for enclosed space entry

18.5.1 Under normal operational circumstances, personnel shall not enter fuel tanks, fuel storage hold spaces, void spaces, tank connection spaces or other enclosed spaces where gas or flammable vapours may accumulate, unless the gas content of the atmosphere in such space is determined by means of fixed or portable equipment to ensure oxygen sufficiency and absence of an explosive atmosphere.[36]

18.5.2 Personnel entering any space designated as a hazardous area shall not introduce any potential source of ignition into the space unless it has been certified gas-free and maintained in that condition.

[34] Refer to ISO 28460, ship-shore interface and port operations.
[35] Refer to API RP 2003, ISGOTT: International Safety Guide for Oil Tankers and Terminals.
[36] Refer to the *Revised recommendations for entering enclosed spaces aboard ships* (A.1050(27)).

18.6 Regulations for inerting and purging of fuel systems

18.6.1 The primary objective in inerting and purging of fuel systems is to prevent the formation of a combustible atmosphere in, near or around fuel system piping, tanks, equipment and adjacent spaces.

18.6.2 Procedures for inerting and purging of fuel systems shall ensure that air is not introduced into piping or a tank containing gas atmospheres, and that gas is not introduced into air contained in enclosures or spaces adjacent to fuel systems.

18.7 Regulations for hot work on or near fuel systems

18.7.1 Hot work in the vicinity of fuel tanks, fuel piping and insulation systems that may be flammable, contaminated with hydrocarbons, or that may give off toxic fumes as a product of combustion shall only be undertaken after the area has been secured and proven safe for hot work and all approvals have been obtained.

Annex

LNG-BUNKER DELIVERY NOTE*

LNG AS FUEL FOR

SHIP NAME: ______________________ **IMO NO.:** ______________________

Date of delivery:

1. LNG-Properties

Methane number **	--	
Lower calorific (heating) value	MJ/kg	
Higher calorific (heating) value	MJ/kg	
Wobbe Indices Ws / Wi	MJ/m^3	
Density	kg/m^3	
Pressure	MPa (abs)	
LNG temperature delivered	°C	
LNG temperature in storage tank(s)	°C	
Pressure in storage tank(s)	MPa (abs)	

2. LNG-Composition

Methane, CH_4	% (kg/kg)	
Ethane, C_2H_6	% (kg/kg)	
Propane, C_3H_8	% (kg/kg)	
Isobutane, i C_4H_{10}	% (kg/kg)	
N-Butane, n C_4H_{10}	% (kg/kg)	
Pentane, C_5H_{12}	% (kg/kg)	
Hexane; C_6H_{14}	% (kg/kg)	
Heptane; C_7H_{16}	% (kg/kg)	
Nitrogen, N_2	% (kg/kg)	
Sulphur, S	% (kg/kg)	
negligible<5ppm hydrogen sulphide, hydrogen, ammonia, chlorine, fluorine, water		

3. Net Total delivered:__________________t, _____MJ _____m^3

Net Liquid delivery: ____________________________GJ

4.	**Signature(s):**
	Supplier Company Name, contact details:_______________
	Signature:______________Place/Port ___________ date:______________
	Receiver:_____________________________

* The LNG properties and composition allow the operator to act in accordance with the known properties of the gas and any operational limitations linked to that.

** Preferably above 70 and referring to the used methane number calculation method in DIN EN 16726. This does not necessarily reflect the methane number that goes into the engine.

Contents

Section
19 TRAINING

19 TRAINING

19.1 Goal

The goal of this chapter is to ensure that seafarers on board ships to which this Code applies are adequately qualified, trained and experienced.

19.2 Functional requirements

Companies shall ensure that seafarers on board ships using gases or other low-flashpoint fuels shall have completed training to attain the abilities that are appropriate to the capacity to be filled and duties and responsibilities to be taken up, taking into account the provisions given in the STCW Convention and Code, as amended.

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